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Engineering, Marine and Welding Exhibition at Olympia — Sixteen-Page Illustrated Supplement

## OLYMPIA ENGINEERING EXHIBITION

Yesterday yet another Olympia Engineering Exhibition opened. We refer to it in that way because what is on this occasion entitled "The Engineering, Marine and Welding and Foundry Trades' Exhibition" has flourished in previous years under a variety of different titles. Yet, despite differences in detail, biennially when the doors are opened, the Exhibition proves to retain essentially the same character. Always there is a strong marine flavour backed by heavy engineering interest. So, although many exhibitions are held at Olympia and some of them relate to sections of the engineering industry the words Olympia Engineering Exhibition can relate, in the ears of most engineers, only to the shows organised biennially by F. W. Bridges and Sons, Ltd. The present exhibition, we are sure, will prove as interesting and instructive as any of its predecessors. We feel sure upon the point even though as we write there are still some 30 hours to go before the doors are opened. For our confidence in that respect has never been disappointed in the past; and we see no reason at all why it should be now. Even before these words are being read we shall be seeking in the Olympia halls, as we have so often sought before, for those entirely new products about which some makers will have withheld information until the show opens, as some always do. Together with many other engineers we shall be looking around noting with pleasure the presence of familiar engineering firms occupying stands in familiar positions; and we shall be noting with deep technical interest how the design of familiar machines, instruments, and other devices has developed in the two-year interval since the Exhibition was last held. To help readers to do the same we publish a special Supplement with this issue.

But above all, those who go to the Exhibition will be renewing acquaintance. For the Olympia Engineering Exhibition is far more than just a trade show. Those who take space at it expect of course to do business. Especially we suppose do smaller firms exhibiting, perhaps, for the first time and very conscious of the cost, hope, through orders received, to recoup themselves for their expenditure. Again and again as the years have passed we have noticed how such small firms, able at first only to afford a small amount of space in one of the galleries have graduated, through success, to larger stands in more prominent positions. Even if—alas!—that progress is not always made, even if some products proudly displayed on one or two occasions subsequently disappear and are heard of no more, the general experience must be that exhibition at the show is well worth while in the business sense. Nor, of course, are larger firms less hopeful than smaller ones, or ones more recently established, that really interested inquiries will come their way. But to improve the look of order books is not and never has been the sole or even the prime object of the Exhibition. For at the very start, when Mr. F. W. Bridges founded the series of Olympia engineering exhibitions, he set out—with no little

foresight—to make the affair a social occasion. Firms which exhibit at Olympia are setting out their products not only before potential buyers but before the critical gaze of every sort and kind of engineer, amongst whom will be numbered a high proportion of the most eminent in the land and not a few from overseas with knowledge of progress made in foreign countries. Those who exhibit, in short, come not only to sell but to learn and discuss ; and many of those who visit the show are not buyers, but men long experienced in the use of the devices they see, and ready with comment and criticism too ! And if indeed, some of the visitors are far too young to be able to contribute much to technological advancement, a salesman must be very hard-boiled indeed, who feels no pulse of pleasure as well as of amusement to hear his product termed, in awe-struck tones, " smashing." Nor is trouble wasted on the youngsters. For who can tell which of them in a few years time may not come back, a welcome visitor, bearing forms of contract in his pocket !

The only regret—curiously enough—is that the Exhibition has nowhere better to go than Olympia. For Olympia is very far from ideal as the venue of a heavy engineering exhibition ; and what a wonderful display could be arranged if only a more suitable hall could be built ! There is a need in London, as near as practicable to its centre, for a hall especially designed for heavy exhibits. It should have easy rail access directly into the hall and road access suitable for really heavy loads ; it should be equipped with heavy overhead cranes and other lifting appliances ; and it should be possible to operate prime movers within it under their own power. In addition there should be all the electric, water, gas and fuel storage facilities likely to be required. Unfortunately there seems little likelihood of the building of such a hall. For its erection would, we suppose, be too speculative a venture to attract private capital ; whilst the Government would find it less attractive for financial support than some more showy project for the creation, near London, of a vast exhibition area with a variety of halls of differing character capable of displaying at a single time a profusion of different kinds of goods. That latter project generates no enthusiasm with us ; and we doubt whether either buyers or those who visit shows educationally are any better attracted by such showmanship than to the smaller specialised exhibitions which are tending to multiply in London, and for many of which Earls Court, Olympia and other halls adequately cater. Unless, therefore, Mr. Bridges cares to build for himself the kind of hall in which he would like to house his show, we expect for many years to come to refer biennially to the opening of a new Olympia Engineering Exhibition !

## METHODS OF SOLVING HIGHWAY PROBLEMS

At the beginning of this century to own and to drive a motor-car was both a luxury and a sport. In 1905 it was reported in the first edition of the *Commercial Motor* that there were 3000 commercial motor vehicles in this country. To-day, fifty years later, there are 1,000,000 commercial vehicles and some 3,500,000 cars. But this growth is small compared with the growth in the United States, where some 60,000,000 motor vehicles are in use, about one to every three people. There, thoughts of luxury and sport are largely thoughts of the past, for the motor vehicle has emerged as a part of the everyday business of life ; in the words of Alistair Cook, in a broadcast a few months ago, " to drive a motor-car is almost as automatic as using one's legs—perhaps more automatic." So it is that the practical American, always ready to adapt himself to changing circumstances, has set about the task of tackling the enormous problems set by the motor vehicle on the one hand and the space it demands both when moving and when stationary on the other. To consider the vehicle without considering the highway is, to our wise American cousins, unthinkable ; to tax petrol heavily and not to provide the tracks, the highways, for the motor vehicles to use, is, as one American has said, " like killing a goose capable of laying very golden eggs."

The account Dr. Glanville and Mr. Moore begin elsewhere in this issue of their visit to the United States last autumn brings home to us the essential difference in attitude towards the road problem in this country and in the United States. And it is clearer than ever before that we, in this country, have hardly begun to measure up to the problem. Motoring has not yet passed out of the stage of being a sport, and since it is regarded as a source of revenue, is still a luxury. With vast new factories in course of construction for building more and more motor vehicles we are inclined to shut our eyes to the problem of the highways and the parking space that these vehicles will need. Our projected increases in expenditure on highways are minute compared with the requirements calculated according to American standards, or indeed calculated on any simple basis, such as, for example, the space occupied by a vehicle on the road, or the maintenance—without improvement—of our present standards of congestion. It is, indeed, not surprising that the assessments of the sums required in the United States, where some 8,000,000 motor vehicles are produced each year, indicate the need for expenditures of (American) billions of dollars—thousands of millions of pounds. It is indeed high time that a logical and balanced assessment of the motor vehicles coming into use in Great Britain and the highways they require should be made on a sound engineering basis. The United States methods of assessment may be a useful guide in doing this. The results would doubtless be frightening in their proportions, but that fact cannot be accepted as a reason for not facing squarely up to the problem. An energy and drive which is producing a new eight-lane super-highway with four railway tracks in the median strip and clearing in the process " a jungle of concrete and steel " and tunnelling right through a United States post office building that stood in its path, provides a lesson in courage and resourcefulness which might well be taken seriously to heart by those who plan improvements to our big towns. For it is not only in the main traffic arteries but also in the big cities that urgent attention is needed in this country as in the United States; and it is in them that costs are high, seemingly prohibitively high. But the lesson of America is there ; it seems that the alternatives are a strangling of the city by the traffic it induces or a costly freeing of congestion by highway building on the grand scale. The widening here and there of the main streets as proposed for London and the construction of a boulevard on the Hyde Park plan are by comparison skirmishes in what must at some time develop into a major war—a major war which we would urge should be conducted with all the help that modern science can give.

It is some years now since the Road Research Laboratory made its assessment of expenditure on transport and travel and showed how vital a part the motor vehicle plays in the national economy ; and for many years the Road Research Board has stressed the urgency of the problem in its annual report. Other competent authorities, too numerous to mention, have done the same. Meantime the laboratory has worked steadily on and has shown how successful the scientific study of many aspects of the road problem can prove ; materials and methods of construction and traffic and safety have all yielded to scientific treatment and many of the things which were, not so many years ago, regarded as imponderables, have been carefully weighed in the balance. Can we not, therefore, expect that scientific study of the overall vehicle-highway relation will yield much of value when employing methods such as those of origin and destination and cost-betterment analysis referred to by Dr. Glanville and Mr. Moore, and can in fact guide us to the road system and the road development best suited to the needs of the nation. The matter is indeed pressing and will become more pressing as new vehicles in their hundreds of thousands pour out upon our meagre highway system and instead of speeding the tempo of industry slow it down by getting in each others' way.

# A Seven Day Journal

### List of Centenarian Firms

IN a Centenary Number to be issued to mark the Centenary of this journal on January 4th next year, there will be included a list of British manufacturing and consulting firms, institutions and societies and journals operating in the fields covered by THE ENGINEER, which will have celebrated their Centenaries by January 4, 1956. To ensure inclusion in the list each such firm or society in the engineering and allied industries, the iron and steel industry, the shipbuilding industry, and any other industries whose activities are commonly reported in THE ENGINEER should inform us about the date of its foundation, its title at that time and its present title, before September 23rd next, addressing the communication to The Editor, "The Engineer," 28, Essex Street, London, W.C.2.

### Material Utilisation

A SUB-COMMITTEE of the research committee of the Institution of Production Engineers has issued a report entitled "Material Utilisation in the Metal Working Industries," which is the result of an investigation into the extent to which British industry is making the best use of materials. A large number of case histories collected from the metal working industries form the basis of the report, which is set out in three main sections consisting of a general survey of current utilisation, a discussion of case studies, and conclusions and recommendations. In the first section of the report it is recalled that improved manufacturing methods and material handling techniques have been introduced in recent years to reduce labour and non-productive costs. It is also stated that the sub-committee hopes to show that improved material economy will, by direct material saving and reduction in machining time, result in a reduction in costs. A short table indicates the wide range of utilisation in a variety of materials revealed by the investigation and points to the possible savings in material cost by a higher percentage of utilisation. To these savings can be added other economies resulting from reduced machining time, less machine capacity absorbed, less swarf for disposal, less shop floor and handling space, and a complementary reduction in overheads. Some thirty-five case studies are discussed and figures are given which compare the total weight, finished weight, and material and machining costs of a variety of components, by both the original and the revised methods, to indicate the order of the economies which have been effected by better material utilisation. The conclusions and recommendations at the end of the report point out that every part requires individual consideration, semi-finished material closer to the shape of the finished part may save process costs, and that high material utilisation is not restricted to large firms. It is further emphasised that high material utilisation is not only fundamental to the original design but is also "everybody's business" in the industry.

### The Radio Show

THE twenty-second National Radio Show opened at Earls Court on Friday, August 26th, two days late because of the strike by members of the Electrical Trades Union. The opening of the show coincides roughly with three main developments in broadcasting—commercial television, high fidelity reproduction of sound, and the introduction of v.h.f. sound broadcasting, coupled with the announcement that transmissions from Wrotham, the first of the B.B.C.'s v.h.f. stations, are now to be at full power. Multi-channel television receivers designed to receive both B.B.C. and commercial programmes incorporate a number of improvements compared with the previous single-band sets; for example, they have automatic gain control in vision and sound, to compensate for differences in signal strength between the stations, thus saving the viewer the trouble of readjusting contrast and brilliance each time a change is made from one channel to another. In general the v.h.f./f.m. sound receivers exhibited take advantage of one or both of the inherent virtues of the new service: the first is the reduction of interference and fading; and the second is the capacity to handle twice the frequency range (up to 10,000 c/s compared with, say, 4500 c/s), which means better reproduction over a correspondingly wider musical range. Various applications of electronics are to be seen at the show. A detailed model of London Airport, with some of the newer equipment for controlling its air traffic, illustrates the part played by electronics in air transport. A model of a commercial aircraft shows the application of radar and other navigational aids and a flight log is exhibited as a means of fixing a pilot's position with the help of ground radar beacons. The Armed Forces are well represented. The Royal Navy is showing a modern wireless office and a comparable installation of 1918. The Army exhibits include a mobile radio-communication station mounted in a 1-ton truck, shown by the Royal Corps of Signals, and models demonstrated by R.E.M.E. to illustrate the use of radar with field artillery. The Royal Air Force is showing a model airfield with typical air traffic control layout and is using the actual cockpit of a "Canberra" bomber to demonstrate the principles of landing with the help of radio aids in bad visibility.

### Air Transport

LAST week Mr. P. G. Masefield, addressed the Town and Country Planning Summer School on the subject of Air Transport, showing the influence exerted by economic requirements on commercial flying. A table of the costs of British European Airways, of which Mr. Masefield is chief executive, showed that staff pay and allowances amounted to 42·9 per cent, the next largest item being fuel at 14·1 per cent. He pointed out that as maintenance and related charges were based on hours flown and revenue on miles, fast aircraft were more profitable, if they were not disproportionately more expensive to fly, and also that the costs, direct and indirect, of landings and take-offs caused operating costs to rise sharply for stage lengths less than the maximum with full payload. The "Viscounts" of B.E.A., in 12,500,000 miles' flying, had earned approximately £1 of revenue and 2s. of profit per aircraft mile: their optimum range was 940 miles. The "Britannia," the most formidable long-range airliner yet flown, would be most economic on a 3750-mile block, when its costs would be 10d. per ton mile. The helicopter appeared to be prohibitively expensive at present because of its low speed and payload, but it was likely that in 1965 fifty-seater versions might link large centres up to 200 miles apart, at fairly high fares. The noise factor would probably exclude vertical take-off, fixed wing aircraft from city centres. Mr. Masefield forecast that lower fares would result from nuclear propulsion and supersonic cruising speeds.

### Lubrication Engineers' Group

THIS week we have received some information about steps which have lately been taken in this country to form an independent group of lubrication engineers. A meeting to discuss the matter was held recently in Sheffield, under the chairmanship of Mr. G. D. Jordan. At that meeting it was agreed that a Group of Lubrication Engineers should be established, its objects being defined as follows: to promote more effective recognition of the importance of the field of lubrication; to assist in every possible way in developing educational facilities for lubrication in industry, at universities, technical colleges, &c.; to arrange technical meetings and discussions on lubrication and allied subjects, and to encourage the exchange of knowledge and experience between members. The next step, we are informed, is to hold another meeting at an early date of all engineers who are interested in this initial proposal. The main purpose of that meeting will be to draw up a working procedure for the group, and determine such matters as qualifications for membership, finance, and a future programme. All who are interested in the development of the group are invited to send their comments and suggestions on the proposals to the Group of Lubrication Engineers, c/o *Scientific Lubrication*, The Old Hall, Broseley, Shropshire.

### The Late Mr. Harold Lister Kirke

IT is with regret that we have to record the death, on August 25th, of Mr. Harold Lister Kirke, C.B.E., who was formerly assistant chief engineer of the British Broadcasting Corporation and one of the pioneers of the very-high-frequency system of broadcasting. Harold Kirke was born in London in 1895. He served, in the First World War, as a commissioned officer in the Royal Fusiliers and later in the Royal Corps of Signals. After being demobilised he joined Marconi's Wireless Telegraph Company, Ltd., and was one of the early collaborators in the pioneering broadcasting system from Writtle, near Chelmsford. In 1924 he joined the British Broadcasting Corporation as a development engineer. A year later he became head of the Corporation's research department—a post which he held until 1949, when he became assistant chief engineer. Ill health forced him to premature retirement in 1952, but not before he had helped to lay the foundations for broadcasting at very high frequencies with frequency modulation, a system of which he was a keen advocate. It will be recalled that it was in 1950 that the first experimental v.h.f. transmitting station was built at Wrotham, about 20 miles south-east of London, and that, after some five years of development, the Wrotham station was officially opened on May 2nd last, as the first step in the B.B.C.'s scheme for v.h.f. coverage of Britain. Mr. Kirke was a Fellow of the British Institution of Radio Engineers, the Physical Society and the Royal Society of Arts. He became an associate member of the Institution of Electrical Engineers in 1935, and a member in 1939. He served as chairman of the Institution's Radio Section in 1944–45, and he was a member of the Council of the Institution from 1947 until his retirement in 1950. Mr. Kirke received the honour of C.B.E. in 1947.

# America's Approach to the Road Problem

By W. H. GLANVILLE* and R. L. MOORE†

No. I

*This article has been prepared following a visit to the United States in October and November, 1954. An outline is given of the new road development plan for America, then in preparation, in which it is proposed to increase the 5 billion dollars at present being spent annually on new roads to 10 billion dollars, over ten years, in order to bring roads up to standards which will be adequate for the increasing traffic requirements of the next twenty years. The article outlines the means by which the estimates were obtained. The backbone of the new plan is a 40,000-mile trunk road network called the "Interstate System." The major road problem of the United States is the provision of adequate urban roads and parking spaces. The report shows how the design of cities is influenced by building all the roads the private motorist wants. On the subject of road safety some of the preliminary results of investigations into ways of reducing the severity of injury to occupants of motor vehicles are given. Some possible reasons are put forward for the better discipline and the decreasing liability to accidents of American pedestrians.*

IN order to understand the American highway scene it is necessary to appreciate the significance of the automobile and its growing importance in both rural and urban communities. The private car is much more than a four-wheeled vehicle providing personal transport ; it is a symbol of social prestige, a symbol of adulthood. People will go hungry and dress poorly to possess a car ; its possession is regarded as a necessity even by authorities administering unemployment benefits. Journeys which we in England would make by air, or rail, or bus, or tube, or cycle, or even on foot, in America are made by car, and public transport organisations are fighting a losing battle with private-car transport in many cities. To an outside observer there appear to be almost pathological aspects of the car worship as seen in America ; cars are used for purposes for which they are not designed, for example, as seats in drive-in cinemas (which are very common in all parts), or for eating in at drive-in restaurants.

The use of the private car is rapidly changing the physical structure of American cities ; outside the houses of all classes are large gleaming cars. New model cars are bigger and more powerful and the American motorist demands roads so that he can drive freely anywhere he pleases. This attitude, common in all sections of the community against a background of growing congestion, accidents, and an acute awareness of the importance of rapid evacuation in case of atomic or hydrogen bomb attack, stirred the Federal Government to set up in 1954 a committee to survey the whole field of road development.

## The Eisenhower Billions

In the United States roads are usually the responsibility of the separate States. Federal funds up to 50 per cent of the cost are allotted to some 630,000 miles of road.[1] When aid is given the projects have to be approved by the Federal Government and uniformity in standards is secured by this means. In 1953 the total Federal aid to highways was 325 million dollars (£116 million) ; this amount comes from the general revenue of the Government. However, the Federal Government excise tax on gasoline of 2 cents per gallon, which realised 713 million dollars in 1953, has usually been much greater than the Federal aid to roads. The Governors' Conference of the forty-eight States has for some time urged that the Federal Government should abandon the gasoline tax field and with it Federal aid to roads, so that the States could raise their own fuel taxes and control their own road plans.

Against this political background Senator Nixon, speaking on July 12, 1954, to the State Governors' Conference from notes prepared by the President, put forward a gigantic road plan for the whole of the United States.[2] The President considered that " obsolete and inadequate highways " were :—

(1) Responsible for transport delays which were " nullifying American gains in productive efficiency."

(2) Causing an " annual death toll comparable to the casualties in a bloody war."

(3) Wasting billions of hours of time and clogging the civil courts with lawsuits.

(4) A serious liability in the event of atom war.

The President quoted expert opinion that an extra sum of 50 billion dollars, spent over ten years, would be required to make " a good start " on the highways for a country with an expected population of 200 million by 1970. In the United States a billion is 1000 million and 50 billion dollars is therefore roughly £18,000 million. At present rates of expenditure new highway construction will cost 50 billion dollars in ten years, so the new proposals will double road expenditure. The money would be utilised for road building in town and country, for the provision of car parks, and the production of a properly articulated system which would solve the problem of speedy, safe transcontinental travel and be able to meet defence needs in the event of atom attack. These Presidential remarks were viewed with suspicion by some members of the Governors' Conference[3] who considered that the road plan was simply a device for postponing the termination of Federal interest in roads. In spite of this political manœuvring, it is clear that the 50 billion plus 50 billion—that is, a 100 billion dollar—road plan captured the imagination of America : " It will bring prosperity to our country," " we cannot afford to be without adequate roads," are typical attitudes.

President Eisenhower's " grand plan " is gradually taking shape. Public Roads Commissioner Du Pont has resigned his post to take over the post of assistant to the Secretary of Commerce, and will have the responsibility of unifying the suggestions of the Governors' Highway Committee and the President's Highway Committee under General Lucius Clay, and of making the recommendations the Administration will send to Congress in 1955. In his message to Congress on January 6th on the State of the Union the President again emphasised the importance of a modern highway system to meet the needs of a growing population, of an expanding economy and of national security.[4] He went on to say : " In further recognition of the importance of transportation to our economic strength and security, the Administration, through a Cabinet committee, is thoroughly examining existing Federal transportation policies to determine their effect on the adequacy of transportation services. This is the first such comprehensive review undertaken by the Executive branch of the Government in modern times. We are not only examining major problems facing the various modes of transport, we are also studying closely the inter-relationships of civilian and government requirements for transportation. Legislation will be recommended to correct policy deficiencies which we may find."

It is clear from this statement that the overall transport system of the country, road, rail and air, is under review. A short time in America makes one realise that national defence requirements are partly responsible for the urgency with which these plans are being tackled. Signs (Fig. 1) prohibiting the use of roads by civilian traffic in the case of war are frequently seen on main roads and serve as a constant reminder of the important part roads are expected to play in civil defence arrangements.

IN THE EVENT OF AN
ENEMY ATTACK ON NIAGARA FALLS
THIS HIGHWAY
WILL BE CLOSED
TO ALL TRAFFIC EXCEPT
CIVIL DEFENSE & MILITARY VEHICLES

**Fig. 1—Notices such as this are common at the side of main roads. They are a constant reminder of the important part roads are expected to play in civil defence arrangements**

Since this article was written the Clay Committee Report entitled " A Ten-Year National Highway Program " has been published‡ ; in general this confirms these conclusions. The committee propose that a new Federal Highway Corporation should be created to administer Federal road finance. The Corporation would have power to issue bonds and utilise the proceeds to grant credits to the States. Of the 27 billion dollars expenditure finally proposed on the Interstate system, 25 billion dollars will be provided by the Federal Government. Where States have already constructed parts of the Interstate system to the required standards, it is proposed that they should receive appropriate credit. The problem of finding the money has not yet been solved. *The Times* of July 29, 1955, gives an account of the rejection by the House of Representatives of the Administration proposal to finance roads by issuing bonds. An alternative

* Director of Road Research, Road Research Laboratory, D.S.I.R.
† Traffic and Safety Division, Road Research Laboratory.

‡ " A Ten-Year National Highway Program " Presidents' Advisory Committee on a National Highway Programme, January, 1955.

Democratic plan for raising the petrol, tyre and other road users' taxes to pay for it was also turned down.—The Speaker of the House thought the vote had killed highway legislation for this session and "probably next year, too."

### The Economics of Highway Development

The Financial and Administrative Research Branch of the Bureau of Public Roads has for some years been investigating the relation between highway expenditure and highway needs and the Bureau's engineer economists must have been concerned in making the 100 billion dollar ten-year estimate of road costs. The method used to estimate future road costs is as follows[5] :—A road, or a road structure, is regarded as a capital investment which gradually depreciates and finally wears out and has to be replaced. Right-of-way for roads has in the past been obtained free of cost from the State and, according to the economists, the value of a road can therefore depreciate to zero value. For high-quality road construction this will take place in about fifty years ; cheaper construction will, of course, depreciate more rapidly. Site preparation and structures are regarded as assets with a life of about fifty years. Between 1914 and 1952, 75·5 billion dollars had been invested in roads at 1953 prices ; the depreciated value of this capital expenditure on highways was, in 1953, including losses due to the abandonment of roads, equal to 37 billion dollars. If the depreciated value is plotted year by year against (1) vehicle mileage and (2) the index of national productivity, the "gross national product,"§ it is found that before World War II the growth in the depreciated investment in highways was increasing at the same rate as vehicle mileage and "gross national product." That is, road investment matched road usage.

During World War II roads were regarded as "expendable." National expenditure on new road construction fell from 1·3 billion dollars (1·3 per cent of gross national product) in 1940 to 0·4 billion dollars (0·2 per cent of gross national product) in 1943. Even in 1952, when construction costs had risen to nearly 3·0 billion dollars, the value of the new road construction still lagged behind the 1938 peak of 1·4 billion dollars because of the reduced money values of post-war years. The result of this curtailment of investment can be appreciated by comparing the trend of vehicle mileage and gross national product which continue to maintain a steady upward increase, while depreciated investment in roads has fallen, but is now maintaining a parallel course which can be brought into line with the other trends by an extra investment of 50 billion dollars spread over ten years. This is about 1·1 per cent of gross national product. Such a line of reasoning prompts many questions, but appears plausible. As actual expenditure is at present at the rate of 5 billion dollars a year, in ten years a total of 100 billion dollars will have to be spent on new road construction ; this is 2·3 per cent of gross national product.

It is interesting to compare proposed United States expenditure on roads with that in the United Kingdom. In 1953–54 in this country 0·6 per cent of gross national product was spent on road construction, improvement and maintenance, but of this only 0·01 per cent on new roads. The proposed United States target on expenditure of 2·3 per cent of the gross national product on new roads would correspond to an expenditure of some £340 million per year in this country.

§ Gross national product may be defined as the sum of the values of all goods, services and investment produced during the period in question.

### Design Requirements for the Interstate System : Estimates of the State Highway Officials

When the Clay committee was formed each of the State Highway Departments was asked to make an estimate of future highway needs. They were supplied with instructions for making the estimate, some details of which are now given. The whole mileage of each State is grouped into ten different categories according to the amount of Federal aid allocated. For example, Group I roads comprise the rural portions of the 40,000-mile interstate system (the equivalent of our trunk road system) ; Group II, the urban portions of the system (about 6000 miles). In 1953, the Bureau of Public Roads estimated that 76 per cent of the interstate system needed improvement or reconstruction. The instructions for completing the estimate for this system are outlined below. Details were asked for expenditure needed in 1955–64 and in 1965–84, in the following manner.

*Expenditure Proposed in* 1955–64.—Estimates are required for the cost of new construction to replace all roads which are either now inadequate or will be inadequate by 1964. The new construction is to be designed to meet all traffic requirements until 1974. A forecast is required of the cost of securing right-of-way over property, so that roads can be enlarged to satisfy traffic requirements until 1984. In no case shall the right-of-way be less than that required for four lanes. Where possible, existing roads, either toll or free, which fulfil the above conditions should be incorporated in the interstate system.

*Expenditure Proposed in* 1965–84.—The programme during this period will consist principally of maintenance and the addition of new lanes after 1974 to accommodate the increased traffic.

*The Design Requirements of the Interstate System.*—In order to give some idea of the kind of highway which will form the trunk road system in the U.S.A. the design requirements for the 40,000 miles of the interstate system are given. The design capacity of the system is based on the thirtieth highest hourly volume of traffic—that is to say, hourly traffic counts throughout the year are tabulated and the thirtieth largest is selected and called the design hourly volume (D.H.V.). This is, in fact, designing a road on the basis of the week-end peak with a little to spare. The road system is to have the necessary physical features to allow the maximum safe speeds shown in Table I to be maintained (the design speed).

Table I—*Design Requirements of the Interstate System*

| Type of road | Operating speed at thirtieth highest hourly volume of traffic in miles per hour | Design speed in miles per hour |
|---|---|---|
| Rural : | | |
| Flat terrain ... ... | 50 to 55 | 70 |
| Rolling terrain ... ... | 45 to 50 | 60 |
| Mountainous terrain | 40 to 45 | 50 |
| Urban ... ... ... ... | 35 to 40 | 50 |

*Control of Access.*—Effective control of access is to be provided throughout the system ; on sections having a D.H.V. (1984) of 1500 or more in rural areas, and 2000 or more in urban areas, full control of access to be provided initially.

*Number and Width of Lanes.*—Traffic lanes to be 12ft wide. The number of lanes are shown in Table II. There are various provisions for increasing the road width to provide climbing lanes on hills for the use of commercial vehicles only.

Table II—*Number of Lanes on Interstate System*

| Area | Year of forecast | Design hourly volume in year of forecast | Type of road prescribed |
|---|---|---|---|
| Rural ... | 1974 | Less than 600 ... | Two-lane with provision for dual carriageway |
| Rural ... | 1974 | More than 600 ... | Dual carriageway initially |
| Rural ... | 1974 | More than 1800 in one direction | Six-lane dual carriageway initially |
| Urban ... | 1974 | More than 2600 in one direction | Six-lane dual carriageway initially |
| Rural ... | 1984 | More than 1800 ... | Provision for six-lane divided carriageway |
| Urban ... | 1984 | More than 2600 ... | Provision for six-lane divided carriageway |

*Shoulders.*—To be 10ft wide in flat and rolling terrains and 6ft in mountainous terrain. Shoulders to be carried over and under structures.

*Medians.*—Medians are shown in Table III :

Table III—*Minimum Widths of Median Strip*

| Area | Minimum median width, ft |
|---|---|
| Rural : | |
| Flat terrain ... ... ... ... ... ... | 60 |
| Rolling terrain ... ... ... ... ... | 30 |
| Mountainous terrain and long structures | 4 (20 at grade intersections) |
| Urban : | |
| Freeways or between widely spaced grade intersections | 15 |
| Difficult locations and long structures | 4 |
| Grade intersections ... ... ... | 20 |

*Grades.*—Maximum of 1 in 33 on flat terrain, 1 in 20 in rolling and mountainous terrain.

*Right-of-Way.*—The minimum rights-of-way are shown in Table IV.

Table IV—*Minimum Right-of-Way Required*

| Area | Type of road | Minimum right-of-way required, ft |
|---|---|---|
| Rural ... | Two-lane highways where provision has been made for ultimate four-lane and control of access | 180 |
| Rural ... | Multi-lane ... ... ... ... ... | 250 |

*Cross Roads.*—All highway-grade crossings to be eliminated ultimately. Necessary right-of-way to enable this to be done to be obtained initially. Similar design data to that given above were given for roads of other types to enable a comprehensive estimate of cost to be worked out.

*The Cost of an Adequate Highway System.*—From the estimates made by the States the Bureau arrived at the following total cost of the proposed work :—

| | Billion dollars |
|---|---|
| Interstate rural roads ... ... ... ... ... ... ... | 13 |
| Interstate urban roads ... ... ... ... ... ... ... | 10 |
| Other Federal aid primary rural roads ... ... ... | 20 |
| Other Federal aid primary urban roads ... ... ... | 10 |
| Federal aid secondary roads ... ... ... ... ... | 15 |
| Other rural roads ... ... ... ... ... ... ... ... | 17 |
| Other city streets ... ... ... ... ... ... ... ... | 16 |
| | 101 |

The total figure is very nearly that obtained by the economists by regarding highways as an investment. It may be noted that it will be necessary to spend 36 billion dollars of the total allocation on urban streets.

*Costs Per Mile of Road.*—About 6000 miles of the interstate system will be in urban areas, but the cost of this will be about 40 per cent of the total of 23 billion dollars. The remaining 78 billion dollars will be spent on the other rural and city roads. The expected construction costs per mile of road are listed in Table V. If control of access is not limited the cost will be between half and three-quarters of the above amounts. It is esti-

mated that about a third of the cost of an urban road is the cost of acquiring right-of-way.

*Financing the New Plan.*—At the present rate of expenditure on new road construction during the years 1955–65 some 50 billion dollars will be spent. General Clay's committee has therefore the job of finding an extra 50 billion dollars and the necessary engineering facilities. The chief problems[6] facing the committee are :—(1) The shortage of trained engineers, (2) the acquisition of right-of-way, (3) the finding of the money.

It is thought by many that there is not so much a shortage of engineers as a misuse of engineers, who frequently do jobs which could equally well be done by draughtsmen and other technicians.

From the public utterances of General Clay it is apparent that his committee is considering the suggestion that the whole of the interstate system should be paid for by the Federal Government from funds provided by the sale of bonds to public investors.

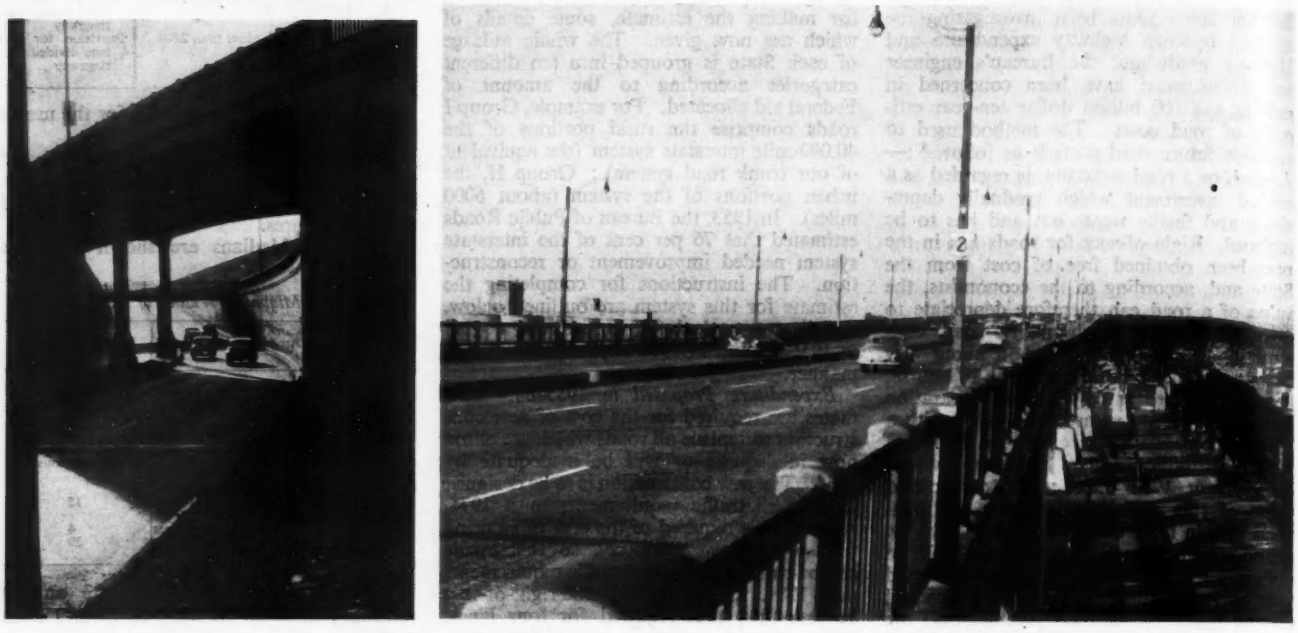

Fig. 2—Examples of roads in Cleveland passing over and under obstacles. On the right is a road carried on a steel structure over roads and docks

Fig. 3—Roads sometimes look like the "Big Dipper"—a four-level interchange on the Hollywood-Santa Ana Freeway in Los Angeles. Construction cost 1,183,700 dollars (£422,750)

TABLE V—*Approximate Costs per Mile of Limited-Access Highways*

| Type of road | Cost per mile in : | |
|---|---|---|
| | Rural areas | Urban areas |
| | Dollars | Dollars |
| 2 lane ... ... | 200,000 to 300,000 | 850,000 to 2,250,000 |
| 4 lane ... ... | 375,000 to 750,000 | 2,300,000 to 6,200,000 |
| 6 lane ... ... | 700,000 to 2,000,000 | 4,500,000 to 12,500,000 |

Repayment would be made from the expected increase in the annual appropriations from Federal taxes on petrol and oil. That is, the extra expenditure will be regarded as a capital investment to be met by borrowing and not from the Federal budget. The remaining part of the 50 billion dollars increase will probably be financed by State and city borrowing.

### ROADS AS PROFITABLE BUSINESS

Roads in the United States are regarded as an investment which should pay good dividends ; "we pay for good roads whether we have them or not, but we pay more if we don't have them," was the theme of a speaker at a recent conference,[7] and this point of view is common among engineers as well as ordinary citizens. Much work has been done on the problems of justifying financially the expenditure required for road improvements. Where alternative schemes are possible the return from each is calculated by determining what they call the "Economic Benefit Ratio,"[8]

where Benefit Ratio=

$$\frac{\text{Annual savings in road user costs}}{\text{Annual costs of the road improvement}}$$

or more fully

$$=\frac{R-R_1}{H_1-H}$$

where $R$ and $R_1$ are the total road user costs

for the original and the improved condition respectively, and $H$ and $H_1$ are the total annual highway costs for the original and the improved condition.

The cost of operating motor vehicles over a length of road has been worked out in some detail : petrol and oil consumption, depreciation and maintenance costs, wear on tyres, &c., are determined, taking into account the state of the road surface, its curvature, gradient, number of intersections, probable vehicle speed, restriction of access, the value of time and the value of convenience. These factors vary, of course, for different types of vehicle. Added to this is the cost of accidents. This may appear in itself to be small, the accident saving on a four-lane limited-access highway being of the order of 0·25 cent per vehicle-mile, compared with other kinds of highways. However, on this basis only it is estimated that it would be economically justifiable to spend an additional 224,000 dollars a mile to limit access to a highway with an average daily volume of 15,000.[8] When all factors are taken into account it is said that a freeway (a limited-access urban highway) is expected to show a benefit ratio of 2 or 3 ; frequently the ratio is as high as 7 or 8 and such projects are given priority.

### Recent Road Building in the United States

During the 1930s, road construction expenditure in the United States averaged about 1·2 billion dollars annually ; in 1943–45 it dropped to about 0·4 billion dollars. In 1953 it had risen to 3·2 billion dollars. These sums are very large amounts by our standards. In 1952 the United States spent nearly 3·0 billion dollars, nearly 200 times as much as was spent on new construction and improvements during 1952–53 in Britain. Even allowing for differences in population the difference is very great, and this is why the visitor to the United States feels he has entered another world, one of unrestricted traffic movement, of high-speed travel for hundreds of miles, where the roadways appear to hop over or under obstacles (as in Fig. 2) and at times are rather like the "Big Dipper" in an amusement park (Fig. 3). In New York, where traffic congestion, especially on a rainy evening, resembles that of London, vast sums have been spent to assist road transport. During the last thirty years, 1·2 billion dollars are said to have been spent and it is estimated that another billion dollars are still needed to cope effectively with the traffic increase expected in the next few years. The cost of some major facilities provided in New York are given in Table VI[9].

Table VI—*Cost of Major Facilities in New York*

| Item | Date opened | Cost (millions of dollars) | Road width |
|---|---|---|---|
| Holland tunnel ... ... | 1927 | 54 | 20ft |
| Goethals bridge ... ... | 1928 | 7 | 42ft |
| Outerbridge crossing ... | 1928 | 10 | 42ft |
| George Washington bridge | 1931 | ·75 | 90ft (8-lane) |
| Bayonne bridge ... ... | 1931 | 13 | 40ft |
| Lincoln tunnel ... ... | 1937 | 87 | 21½ft |
| Duplicate Lincoln tunnel | Under construction | 100 | — |
| Freight terminal ... ... | 1932 | 19 | 198 berths |
| Union truck terminal ... | 1949 | 10 | 142 berths |
| Bus terminal... ... ... | 1950 | 24 | 140 loading platforms |

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*(To be concluded)*

# Science and the Scientist

By SIR ROBERT ROBINSON, O.M., F.R.S.

*The British Association meeting at Bristol opened last Wednesday. Here we print some abstracts from the presidential address to the Association. Sir Robert, by drawing upon examples of historic scientific researches, endeavours to define and distinguish between science and scientists and he has as a conclusion something to say about technologists and how best to produce them in sufficient numbers.*

WHEN the secretary, as agent of the council, asked me for the title of this Address, I was more than usually preoccupied and selected "Science and the Scientist" because I thought it clay that could be modelled into almost any desired shape. However, there was at the back of my mind the feeling that the functions of the two are not always clearly understood and distinguished, so that there is more than a little confusion of thought in some quarters, especially in the use of the word "science." The subject is not at all controversial, but I will ask for your indulgence to state once more the generally accepted definition, clearly implied in common consent if not the subject of any recent manifesto.

Science is simply the record, enshrined in the literature, of the system of knowledge and of the conceptions correlating parts of that system.

It is fundamental that such knowledge cannot be based on dogma or authority of any kind, nor on any intuition or revelation, unless indeed it be of the Book of Nature that lies open before our eyes. We need not dwell on the processes of acquiring knowledge by observation, experiment, and inductive and deductive reasoning. The study of scientific method, both in theory and practice, is of great importance, but this topic requires separate treatment. Further, it is inherent in the philosophy that the record may be imperfect and the conceptions erroneous ; the potential fallibility of our science is not only acknowledged but insisted upon. Still there are degrees of uncertainty and even the apparent revolution in physics that has occurred in the twentieth century has not so much superseded the older teaching as supplemented and extended it by wider generalisation.

The improvement of knowledge by successive approximations is fundamental and it is worth while to consider some illustrations. A very simple example of the improvement of a nearly true statement of a relation is that of the Boyle-Charles law. This stated that the volume of a gas is directly proportional to the temperature and inversely proportional to the pressure. It can be expressed as $pv=RT$. This works very well for most practical purposes, but it is not quite correct, especially at higher pressures. In 1873, van der Waals pointed out that the volume ($v$) taken should be lessened by a quantity ($b$) related (but not equal) to the volume of the molecules themselves, i.e. $v-b$ for $v$. The pressure ($p$) should be increased by a quantity $a/v^2$, which denotes the cohesion of the molecules.

With the expression,

$$\left(p+\frac{a}{v^2}\right)(v-b)=RT,$$

a much better agreement with the experimental data was obtained, but it was still not absolutely accurate and more or less successful modifications have been suggested. The "ideal" gas which obeys the Boyle-Charles law may perhaps be compared to the "ideal" railway that conforms to Bradshaw. The divergence from the ideal in the performance of a railway becomes greater when the traffic is congested and this factor is not unlike the $b$ of van der Waals. But railways are much worse than gases, chiefly due to the appearance of the human factor, which is quite incalculable.

Where the material can be directly apprehended by our senses, aided perhaps by devices such as cameras, microscopes and telescopes, there can be little doubt as to the validity of the record, though it may need some adjustment of errors of observation and of the value of any magnitude that is involved. The uncertainties are then largely concentrated on the conceptions and generalisations which have been based on the ascertained facts. May I be excused if I refer to the subject I know best in illustration. The molecular structures of the chemist are not directly perceptible, but must be deduced from observations on collections of very large numbers of molecules, and yet a most remarkable system has been evolved which even forms the conventional basis of patents and is recognised as valid in courts of law. The degree of uncertainty is indeed not much increased by the fact that we cannot see these structures.

Leaving aside philosophical dubieties about reality we can say that the limits of our knowledge in this field are somewhat as follows. That the atoms exist as entities, but the problem of the nature and constitution of the atoms themselves has not been fully solved ; rapid progress is being made. We know the arrangement of the atoms in the vast majority of the species of molecules which we find in Nature and we have learned how to construct molecules, even those of a highly complex pattern. The defences of some of the last strongholds are in process of being breached.

Justification of scientific theory has been obtained by the success of predictions and by the unanticipated convergence of more than one line of approach. This is a commonplace of every part of science and the examples to be mentioned could be almost indefinitely extended. In all the cases the degree of coincidence becomes so great as to carry conviction that we have been vouchsafed, if not the whole truth, at least something very closely related to it.

Even the routine predictions of astronomers are a perpetual source of wonder but the circumstances of the discovery of Neptune were sensational. In 1843–4, J. C. Adams, of Cambridge, found the that perturbations of the orbit of Uranus could be fully explained by the existence of an outer planet and he accurately identified the position in which it should be found. Quite independently, Le Verrier, of Paris,

came to exactly the same conclusions and was more fortunate than Adams in securing the quick co-operation of practical astronomers, with the result that Neptune was discovered in the predicted place in the Heavens. It proved to be of the size expected and later was found to follow the expected orbit.

Again, near the beginning of the second decade of the century, Albert Einstein stated that his relativity theory required that the rays of light should be bent under the influence of a gravitational field. He was able to calculate the magnitude of the expected effect. Confirmation came from observations made on the occasions of the two next following total eclipses of the sun. This success was naturally particularly welcome in view of the novelty of the theoretical background and it doubtless accelerated the development of the new physics based on the work of Planck, Einstein and other pioneers.

A third example of prediction is the successful release of nuclear energy, especially in the so-called hydrogen bomb. We must not allow the horror of the possible misuse of the weapon to blind us to the spectacular triumph of the achievement. It showed very plainly that nuclear physicists had been thinking on the right theoretical lines. Let us hope that they will continue to do so, 100 per cent and not 99·9 per cent. These matters are shrouded in secrecy but Press reports have suggested that just as the hydrogen bomb is initiated by a Mark I atomic explosion, so the hydrogen bomb in its turn can initiate a vastly greater uranium explosion. In biological processes energy is taken up in steps by suitable relays to high levels, and an ordinary scientist cannot help wondering whether every possibility of setting fire to the lighter elements has quite certainly been excluded, if nuclear relay is taken to further stages.

Do we really know enough about nuclear reactions to be sure there is no loophole ? Has every conceivable case been considered ? The physicists appear to be cocksure that this is so ; they claim the 100 per cent. But just as it is necessary that " justice shall be seen to have been done " I submit that it is desirable that the inner circle of advisers to Governments should not only be right but be " seen to be right." This can only be secured by a relaxation of secrecy on the scientific aspects of nuclear energy developments and by some form of international consultation before novel and greatly increased releases of energy are attempted.

The second class of welcome confirmations was the illumination of a topic from two or more distinct sources. This is now a commonplace of many sciences, for example, again, of organic chemistry. Analytical researches lead to the determination of a molecular structure which may be confirmed, possibly after the lapse of years and in a different laboratory, by synthesis of the substance the molecules of which should possess that structure. If the synthetic product proves to be identical with that isolated from natural sources, the whole system of reasoning both on the analytical and synthetic sides receives important support. Even more striking has been the validation of the conclusions of chemists by X-ray crystallography. At first this led to the confirmation of established structures, often with some additional information about the arrangement of the atoms in space. Later the X-ray studies were accessory to the first analytic studies.

There is no philosophical line of demarcation that separates one branch of learning from another though the demeanour of many so-called humanists suggests that they perceive one. It is not necessary or desirable to pursue this unprofitable discussion ; our brother scientists on the Arts side will doubtless work out their own salvation. But it is opportune to add another voice of protest against the often repeated assertion, that " culture " is the preserve of students of some particular branches of knowledge, and is denied to others. What is meant by " culture " ? If it is the ability to think clearly and to express thoughts in language, what evidence is there that physical and biological scientists lack these qualities ? The acerbity that characterises much of the anti-scientific propaganda strongly suggests that its basis is defensive rather than offensive. In the meantime these persistent attacks do a great deal of harm by suggesting to young people that they will become automatons if they devote themselves to physical science and that in such a life they will not experience the warmth of human feeling. What a travesty of the facts this is ! The scientific discipline is indeed a hard one but it is most rewarding and full of living drama.

Before straying too far from actual science I would like to say something about the use of speculation, which should always arise from some correlation which was hitherto unknown or unnoticed, or the significance of which has been underestimated, or thought to have been underestimated. In the early stages it may be discouraging to study the literature ; one can always find reasons there for believing that a new idea is not worth pursuing, or for that matter for saving oneself the trouble of doing an experiment. Later, having worked up an internal, self-generated pressure of enthusiasm, it is obligatory to face the hard facts already on record. Then, instead of weakly accepting a rebuff we shall at least put up some fight with " but on the other hand it might be that——." At this point it may be realised that something really has been overlooked by one's predecessors and new crucial experiments must be devised to resolve one dubiety after another. Herein lies the safeguard, the final court of appeal is Nature herself.

An important aspect of science is its universality, and its fully international character only rendered possible by the axiomatic freedom it enjoys from authority and dogma. There is no such thing as British, or German, or Russian, or Jewish science though it is true that the genius of many peoples has enabled them to make characteristic contributions.

Science as a common international possession and the world-wide co-operation in its development must be bulwarks of peace. Here we have a realisable asset of the greatest possible positive value. The brotherhood of scientists is a reality. It is fortunately not unique ; there is a similar fraternity among sportsmen, musicians, chess-players, and other categories of enthusiasts, not encumbered by the so-called ideologies.

Another feature of the complex make-up of the scientist is that he is a citizen and owes a duty to the State. This leads to obvious conclusions in most respects but where do we stand in regard to the invention of military weapons ? In war-time few of us entertained any doubts about this ; it was our clear duty to help our country to the best of our ability. Now it is a matter for the conscience of the individual, taking into consideration that we have not yet achieved a real peace. The position is one of unstable equilibrium and it still seems that as citizens we should do all in our power to strengthen the hands of our leaders, in whom we have placed our trust, and who we believe are sincere in their desire to achieve universal peace among the nations. Even the terrible nuclear-energy weapons must be developed by our scientists in peace-time so as to build up the necessary potential of deterrence, our only defence against extinction. Finally, I want to say a word about technology and technologists. Dr. Holmyard and Professor Singer have, in the first volume of their monumental work on the History of Technology, pointed out that it all started with handicraft. The modern technologist is still a man with know-how and can-do, whether he be technician, craftsman, designer or supervisor, and he is equipped with knowledge of general and special scientific and engineering subjects. It is generally agreed that we have far too few technologists in this country and that our economic survival is improbable unless we take some drastic steps to remedy the situation. The proposals that have been made are admirable as far as they go, but, in the opinion of many who are well qualified to judge, they do not go nearly far enough. It is doubtful whether any scheme tied to existing Institutions can meet the requirements and to come right down to ground level. I suggest that we need a " Technology Grants Committee," independent of any other body and with power to expend a very considerable sum of money. This idea has probably already been adumbrated. In which case I think it should be supported.

## Linear Accelerators at the Science Museum

A SMALL group of exhibits typifying linear electron accelerators has been assembled in the Atomic Physics Collection of the Science Museum, South Kensington, London, S.W.7. It illustrates recent developments in electronic techniques which have enabled electrons to be accelerated to very high speeds without the use of correspondingly high voltages. Whereas cyclic accelerators such as the betatron and synchrotron are probably more useful for purely research work, travelling-wave linear accelerators offer some advantages in the production of penetrating X-rays for hospital radiotherapy, and they are being installed in a growing number of British hospitals. In the new group of exhibits there are sectioned parts of a full-size Mullard accelerator ; an ingenious mechanical model lent by the Metropolitan-Vickers Electrical Company, Ltd., to illustrate the principle of the travelling-wave accelerator ; several diagrams depicting the construction and operation of this class of equipment ; and a series of photographs showing modern linear accelerators being used in Hammersmith hospital and in the Megavolt Treatment Unit at Newcastle upon Tyne. Other kinds of particle accelerators which have recently been put on view in the Science Museum include a betatron presented by the Clarendon Laboratory, Oxford, and a model of the Philips cascade generator at the Cavendish Laboratory, Cambridge.

DOUBLING A TRUNK ROAD.—The Ministry of Transport and Civil Aviation has stated that, by making full use of up-to-date machinery, the building of a second carriageway, 1¼ miles long, on the Cambridge trunk road from London, has been completed four months ahead of the scheduled time. The new carriageway, the cost of which is put at £85,000, extends the existing dual carriageway system from the North Circular Road junction to Bury Street, Edmonton. It provides for two lanes of traffic and incorporates an experimental section built to a specification prepared by the Road Research Laboratory of the D.S.I.R. The work has been done by Fitzpatrick and Son (Contractors), Ltd.

# Influence of the Engineer on Sea Transport and Trade

By DR. S. F. DOREY, C.B.E., F.R.S.

*In his Presidential Address to Section G of the British Association meeting at Bristol, delivered yesterday, Dr. Dorey reviewed the history of the developments in marine engineering from the end of the eighteenth century onwards. Here we print the latter part of his Address, covering the period from* 1918 *onwards.*

FOLLOWING the 1914–18 war, shipowners were faced with the problem of rebuilding their total tonnages to make good the losses during the hostilities. They had struggled to achieve this aim without subsidy when trade eased and competition became keen to secure freights. Reductions in fuel costs were of vital importance and it was this aspect which received the attention of engineers. The triple-expansion steam engine then operating with saturated steam supplied by Scotch boilers of 200 lb per square inch working pressure offered fuel consumptions of 1·6 lb of coal or 1·1 lb boiler oil/i.h.p.-hr. Steam engine makers soon developed improved designs incorporating such features as poppet valve gear and uniflow exhaust of cylinders, and capable of operating with superheated steam at total temperatures approaching 700 deg. Fah.

The inability of the reciprocating engine to utilise all the possible expansion of the steam due to limits imposed on the size of the l.p. cylinders was overcome by the fitting of exhaust steam turbines. This was no new feature, for Parsons used a reaction turbine supplied with exhaust steam from two reciprocating engines and driving an independent shaft directly, in the triple-screw steamship "Otaki," completed in 1908. Before this arrangement was superseded by the geared turbine for passenger ships a number of other installations were completed, including those of the "Olympic" and "Titanic."

The arrangement first fitted in a single-screw ship in 1926 was the Bauer-Wach system, in which the drive from the turbine was transmitted through double reduction gearing and a fluid coupling back to the reciprocating engine main shaft. Other manufacturers preferred electrical to mechanical transmission and in these cases the exhaust steam turbo-generator with either a.c. or d.c. output supplied an electric motor mounted at a convenient position on the main propulsion shafting.

Reheating of the steam before admission to the m.p. cylinder of the reciprocating engine also offered appreciable improvement in performance. The direct method of raising the conditions of the h.p. exhaust employed a tubular heat exchanger supplied with superheated steam direct from the main boiler unit. As an alternative an exhaust turbine was used to drive either a d.c. generator, which supplied electrical heating elements, or a steam compressor.

Each of the improved steam reciprocating installations had its own particular merits and champions. Fuel consumptions of just under 1 lb coal or 0·8 lb oil/i.h.p.-hr. could now be offered and these represented appreciable savings in overall fuel costs. Nevertheless, progress in the oil engine field had been so marked as to offer a serious rival to the steam reciprocator.

In 1914 Wm. Doxford and Sons, Ltd., of Sunderland, ran endurance trials on a single-cylinder, two-stroke cycle, heavy oil engine which embodied the opposed piston principle and developed 450 b.h.p. at 125 r.p.m. This represented a major advance in the power output of a single cylinder. During the 1914–18 war the performance of both four-stroke and two-stroke oil engines progressed rapidly and this was assisted by the adoption of solid injection of the fuel, an important departure from the diesel principle.

By 1921 two-stroke engines of four cylinders were providing 3000 b.h.p. on a single screw, but four-stroke engines nevertheless predominated in marine practice. Four years later, double-acting engines of the latter type displayed single-cylinder outputs of 1100 b.h.p. The twin-screw motorship "Gripsholm," for example, was directly propelled by two six-cylinder engines of this type, 33in in bore and 59·1in stroke, with a total output of 13,500 b.h.p. at 125 r.p.m. Doxfords soon challenged this achievement by building engines of the two-stroke type described and the 5000 total b.h.p. represented 1250 b.h.p. per cylinder.

At this time many of the service problems experienced with two-stroke cycle oil engines had been surmounted and a number of engine builders who had previously favoured four-stroke engines now regarded the former as a better proposition. In consequence the passenger liners "Britannic" and "Georgic," completed in 1930 and each fitted with two ten-cylinder engines of 20,000 combined b.h.p. represented a peak in the progress of the four-stroke type. Thereafter preference for the various two-stroke engines prevailed until the present day, when they form no less than 80 per cent of the main oil engines fitted in ships. Further, the fitting of Buchi superchargers to engines of the four-stroke type, although giving improved performance, had little effect on the predominance of the two-stroke engines.

By 1934 two-stroke engines were supplying up to 7000 b.h.p. on a single screw and the replacement of cast iron bed-plates, entablatures and columns by welded fabrications in mild steel did much to reduce the weight and size of the engines. In addition, renewed attention was given to the use of exhaust gases to raise steam in waste heat boilers which augmented the supply from the donkey boilers and reduced the overall fuel consumption of the auxiliary machinery.

After that time the power of heavy oil engines continued to increase steadily. In post-war years, however, the successful adoption of a moderate degree of supercharging in two-stroke engines had provided 30 to 35 per cent increase in power with mean indicated pressures of up to 130 lb per square inch. Engines are already under construction with single-cylinder outputs of 1650 b.h.p. and further increases to 2200 b.h.p. are contemplated. Large slow-running engines, therefore, develop 10,000 to 17,000 b.h.p. and offer a serious challenge to the geared steam turbine for the propulsion of single-screw tankers and cargo ships. Without increase in the weight of the installation, two medium-speed oil engines coupled through 2 : 1 reduction gearing to a single shaft have also been employed to develop these powers. The gearing is protected from engine excited torque fluctuations by either fluid or, more recently, electro-magnetic couplings installed between engines and pinions. Moreover, such arrangements show considerable advantages during manœuvring. Although two-stroke engines are usually used for a propulsion unit of this kind, highly supercharged four-stroke engines are available when lower powers are required.

The following ships have machinery installations which illustrate these points :—

(1) The single-screw motorship "Polarbris" is directly propelled by a six-cylinder Doxford engine which develops 8000 b.h.p. at 104 r.p.m.

(2) The M.V. "Caraibe" employs two two-stroke engines developing 14,000 b.h.p. at 215 r.p.m. to drive a single shaft running at 117·5 r.p.m., through electro-magnetic couplings and single reduction gearing.

(3) The cargo liner "Lichtenfels" is fitted with two highly supercharged four-stroke oil engines of 5600 b.h.p. at 250 r.p.m., which is transmitted through fluid couplings and reduction gearing to a single screw running at 105 r.p.m.

These single-acting engines of crosshead type built by M.A.N. represent the latest trend in this class of four-stroke design. A brake mean effective pressure of 227 lb per square inch is obtained by supercharging at 35 lb per square inch pressure from a fourteen-stage axial compressor, with intercoolers, driven by a three-stage exhaust gas turbine.

High speed, medium power, two and four-stroke supercharged engines of vee and delta type with up to twenty-four cylinders are also available for merchant ship propulsion. Multiple units, geared or electrically connected to a single screw, offer advantages of reduced space requirements and low total weight per horsepower developed. Shipowners prefer the slower-running engines, however, and they are not yet convinced that engine changes and shore repair and servicing establishments are the answer to rising maintenance costs.

Modern oil engines have excellent fuel consumptions of about 0·32 lb oil/b.h.p.-hr., which correspond with overall efficiencies of 40 per cent. The most important feature of slow and medium-speed engines has been their recent conversion for burning boiler or residual grades of oil, however. The use of these fuels can provide a saving in fuel costs of up to 30 per cent. This achievement has given the oil engine a substantial lead over rival prime movers, but the approach towards the theoretical efficiency leaves little scope for greater economy.

Before the 1914–18 war, water-tube boilers had superseded those of cylindrical design in warships and had proved superior in performance and operation. The working pressure of boilers in merchant ships advanced slowly during the first quarter of this century and the maximum employed was little in excess of 250 lb per square inch. Over this period the cylindrical boiler predominated throughout the whole power range of steam machinery. A considerable number of water-tube boilers were installed in merchant ships during the Great War, however, but their satisfactory service did little to dispel the prejudice against them except in America, where wartime construction comprised the major part of the merchant fleet. The development of economical steam-turbine machinery installations during the 1920s demanded h.p. inlet conditions which could no longer be met by cylindrical boilers and the water-tube type now controlled the field of high-pressure and high-temperature steam production.

The benefits of advanced steam plants

were soon evident by the appreciable reductions in specific fuel consumptions. The S.S. "Duchess of Bedford," completed in 1928, was fitted with Yarrow boilers with a working pressure of 340 lb per square inch at 670 deg. Fah. total temperature. The fuel consumption of the main machinery was recorded as 0·57 lb/s.h.p.-hr. When compared with a Scotch boiler installation of eight years earlier a fuel saving of at least 15 per cent was evident. Three years later the "Empress of Britain" entered service and her full power of 60,000 s.h.p. was developed by turbines supplied with steam at 425 lb per square inch and 725 deg. Fah. On trials the same fuel consumption was recorded, but in this case it represented the all-purpose requirements. An appreciable advance in the use of higher steam conditions occurred in 1936 when construction commenced on the turbo-electric tanker "J. W. Van Dyke." The two Babcock and Wilcox boilers of this ship were designed for a maximum working pressure of 675 lb per square inch, the superheater outlet steam being at 625 lb per square inch and 835 deg. Fah. The fuel consumption of the main machinery was approximately 0·51 lb/s.h.p.-hr. In the sister tanker, "Robert H. Colley," laid down in 1938, the steam temperature was raised to 910 deg. Fah., which was the most advanced condition used in merchant ships in the pre-war and early-war years.

Some remarkable high-pressure installations were also completed, notably the 3200 lb per square inch of the Benson boilers in the "Uckermark," 1990 lb per square inch by Loeffler type in the "Conti Rosso" and the "Potsdam," with 2650 lb per square inch working pressure. Such high pressures were rarer, however, and the main object has since been for pressures below 1000 lb per square inch with high degrees of superheat.

Water-tube boiler makers were active in their design advancement and by 1938 boiler efficiencies of 87 per cent were possible. This was partly responsible for the low overall fuel consumptions of propulsion machinery. Of equal importance were the increases made in total heating surface and the rates of evaporation produced by single boilers for this permitted boiler plant of reduced size and weight. In addition, high quality fusion welded joints replaced those of riveted type in the fabrication of boiler drums, and by this means weight saving alone exceeded 1¼ tons per drum. As an indication of the merits of water-tube boilers the French liner "Normandie" may be cited. It was desired originally that cylindrical boilers should supply the steam for her 160,000 s.h.p. turbine machinery, but the size of the ship would have been such that no existing harbour could accommodate her. In the end, therefore, twenty-nine water-tube boilers were used and steam was then raised at 400 lb per square inch pressure and 620 deg. Fah.

In America the Scotch boiler had practically died out by 1939, for a year later special arrangements had to be made to supply boilers of this kind for sixty cargo ships ordered by Britain. In Britain, however, the cylindrical boiler has retained some of its popularity for both main and auxiliary steam generation, due to its rugged characteristics, and it is usual practice to use water-tube boilers where steam pressures exceed 300 lb per square inch. Steam-turbine installations at present engine ships of 50,000 s.h.p. per screw or 200,000 total s.h.p. and as greater powers will not be required for some years, it is natural that research should be concerned with reducing fuel consumptions well below 0·5 lb/s.h.p.-hr. and developing more compact plants. Economical units incorporating one or more reheat points are at present under consideration and it seems that gas-fired reheaters will supersede those of steam type. Increased steam conditions at the h.p. turbine inlet still present a major source for improved economy. The tanker "Atlantic Seaman," which has been in service for five years, has a turbine plant working with inlet steam at 600 lb per square inch pressure and 1020 deg. Fah. This machinery remains in advance of other merchant ship installations and fabrication, design and service problems of high temperature materials are largely responsible for this position.

Of the ships at present under construction, all in excess of 20,000 tons will employ geared steam turbines for main propulsion. Within the size range 100 to 20,000 tons, 70 per cent will be propelled by oil engines, while the remainder, with isolated exceptions, will have steam reciprocating or turbine main machinery. Turbo- or diesel-electric transmissions have not proved popular although restricted gear-cutting machine capacity increased the number of installations of these kinds during the last war. In some instances, however, turbo-electric main machinery has been preferred for large oil tankers in order that the main generator could be used to supply the cargo pumps when in port.

Both tankers and ore carriers have increased in size to meet the needs of supplying the expanding oil, chemical and metallurgical industries. Vessels of these types at present rival large passenger ships in size but retain single-screw propulsion. To meet these conditions steam turbine manufacturers in particular have developed compact power plants developing up to 20,000 s.h.p. Further progress is continuing in this direction and double-reduction gearing in particular is the subject of extensive researches. The problems of successful transmission of gear tooth loads of two to three times recognised pre-war levels have not yet been satisfactorily solved and surface hardened and ground gears are at present under consideration.

In recent years other forms of prime mover have been considered for merchant ship propulsion, but so far these have not proved sufficiently attractive for general service.

The marine gas turbines at present under development for marine propulsion purposes are of open cycle type. In general, the h.p. turbine drives an axial compressor as an independent unit, while the l.p. provides the useful output and exhausts through a heat exchanger which preheats the inlet charge to the combustion chamber. The designs vary considerably, but can be considered in two main categories. The first covers those of light-weight construction, under 7 lb per horsepower, and developing up to 6000 s.h.p. The h.p. inlet temperatures of about 820 deg. Cent. limit the life of the hot parts to little more than 1000 hours. Units of this kind power light naval craft only, for a satisfactory life in excess of 20,000 hours is required for the main engines of merchant ships. This is at present obtained by limiting the top temperature to below 700 deg. Cent. in medium-weight plants of 25 lb to 30 lb/s.h.p. Both classes of gas turbine have overall efficiencies of about 20 per cent, but when the long service reliability of the latter has been established, advances in top temperatures and design should provide fuel consumptions below 0·5 lb/s.h.p.-hr. Since these engines cannot be run astern, either electric transmission, reversible pitch propellers or reduction gearing with reverse trains must be used. Of these, the last quoted is receiving the greatest attention and is likely to predominate in future installations.

In France, remarkable progress has been made recently in a power plant comprising a free piston gas generator and geared gas turbine. Turbine inlet conditions of four atmospheres pressure and less than 500 deg. Cent. are used as the peak temperature of the thermodynamic cycle occurs in the cylinder of the free piston gas generator. Overall thermal efficiencies therefore approach those of existing oil engines and are represented by a fuel consumption of 0·39 lb diesel oil/s.h.p.-hr. The problem of manœuvring does not apply in this instance as astern wheels are incorporated in the turbine shaft.

The size of the gas generator has been standardised so that equal reliability may be obtained with all units. High-power plants will, therefore, comprise multiple units supplying one or more geared turbines. The first main marine installation of this kind was installed in the 800 tons deadweight "Cantenac," completed in 1954, and other ships at present under construction will be similarly fitted.

The construction of two submarines for the U.S. Navy, in which the heat developed in a nuclear reactor is used to raise steam for supplying both main and auxiliary turbine machinery, has resulted in wide speculation of the possible adoption of similar power plants for merchant ship applications. Indeed, such an impressive statement that the fissioning of 1 lb of uranium produces heat equivalent to 2300 tons of coal or 300,000 gallons of oil raises visions of revolutionary changes in the design of merchant ships and their machinery. As these changes would solve many existing problems, it seems that thermal reactors must eventually provide the energy for steamship propulsion. When this event will be possible depends on the rate of progress made in reducing to more attractive levels the weight, size and cost of reactors and screening and the satisfactory solution of control and maintenance problems. It appears that the power-weight ratios of these units will be better suited to the higher-powered plants of large cargo and passenger liners than to the many low-powered installations in smaller ships. Undoubtedly, the latter will continue to be engined with conventional prime movers.

In the submarine U.S.S. "Nautilus" purified water under high pressure forms the primary coolant which extracts the heat from the thermal reactor. The steam then raised in heat exchangers is at relatively low pressure and temperature, probably not more than 180 lb per square inch and 440 deg. Fah. Consequently, geared steam turbines of moderate thermal efficiency are used and high temperature is confined to the primary coolant section. In effect, the controlling factor is the rate at which heat can be extracted from the small volume of the thermal reactor and providing this is adequate to meet the demands, thermal efficiency is of only secondary importance. Moreover, raising the thermal efficiency by adopting different reactors and primary coolants which produce steam at higher temperatures and pressures does not result in longer duration for the same amount of nuclear fuel as with oil-fired installations. It is related to the size of plant, however, and for this reason fast reactors and liquid metal primary coolants may be superior for steamships.

While the developments of main machinery installations in little over 150 years have made a substantial contribution to the expan-

sion of world trade, auxiliary machinery has also played a part. The luxury of a modern liner stems, in part, from this source. It is just over seventy-five years ago that Inman first employed electricity on board ship to supply arc lamps fitted in the saloon of the "City of Berlin." From that time the applications of electricity increased markedly and the size of the d.c. generating plant grew to meet these needs. In more recent years a.c. systems have become prevalent in both oil tankers and passenger liners. In addition, diesel-driven generators have largely superseded those of steam reciprocating engine-driven types. Large liners invariably employ steam turbines for both main and auxiliary purposes, but the installation of the Greek liner "Olympia," completed in 1953, departed from this practice by employing steam turbines for main propulsion only, the auxiliaries being exclusively diesel-electric. In cargo ships a new departure has been the use of a free piston gas generator supplying the gas turbine of a turbo-electric set and a number of normal gas turbine sets are now under construction and will soon be in service at sea.

Many trades flourished with the introduction of refrigeration machinery for shipboard purposes. The meat trade originated in 1880 when the S.S. "Strathleven" arrived in London from Australia carrying 40 tons of frozen meat. This event was given prominence in the world press and laid the foundation of a new trade which was to grow at a remarkable rate. Prosperity was brought to Australia, New Zealand and South America, while the peoples of Europe were supplied with cheap foods, at least in pre-war years ! New Zealand alone exported 760 tons of meat in 1882 ; three years later the figure was no less than 15,000 tons, and doubled again in another decade. It can truly be said that few engineering achievements have had such revolutionary effects on world trade and prosperity. To-day, *Lloyd's Register Book* contains the details of nearly 1000 shipboard refrigeration installations on which the fish, meat, fruit and farm produce trades depend.

Until recently the holds of the ship were the refrigeration chambers, but a few companies are introducing separate refrigeration containers. In effect, these comprise large portable refrigerators requiring only an electrical supply. Containers of this type offer considerable scope for the handling of delicate low bulk cargoes, but they are unlikely to replace the existing system for storing bulk frozen cargoes.

Possibly the most extensive use of auxiliary machinery arises in factory ships. The commercial advantages of employing a whale factory ship which can deal with the catches of a number of whalers have given impetus to the introduction of long-range fish factory ships. The "Fairtry," completed in 1954, is the largest trawler afloat and incorporates modern factory equipment for dealing with the catch. This trawler has a stern opening and ramp and when the fish is landed automatic electrically operated machinery undertakes the process of heading, filleting, skinning, cleaning and packing. Mechanical conveyors operate between the last operation and the deep-freeze chambers used for storage. With additional plant for cod liver oil and fish meal production, this trawler may well represent the future means of meeting the expanding fish industry.

This industry has many existing difficulties so far as the economic operation of distant water trawlers is concerned. Already existing trawlers have been modified to include deep freeze holds in which the catch can be stored. It is anticipated that the new system of storing the catch will overcome some of the problems of marketing in the peak spring and summer periods by enabling the surplus, stored in aluminium alloy containers, to be transferred and kept in shore refrigeration warehouses. Normally, the surplus must be disposed of to fish-meal factories, thereby incurring an appreciable loss.

An examination of the history of one particular field of engineering has indicated that the remarkable increases which have occurred in the prosperity of nations, during the last century and a half, can largely be attributed to the achievements of the engineer. It is also true that the countries which have encouraged engineers and industry enjoy the highest standard of living. To-day, we aim to improve our living standard still further and, at the same time, assist other countries to do likewise. That the engineer is continuing to play his part is evidenced by the high rate of technical progress maintained during post-war years.

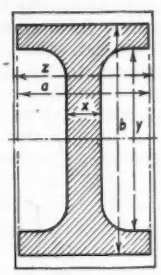
# Loads in Locomotive Coupling Rods

By W. A. TUPLIN, D.Sc., M.I.Mech.E., A.I.Loco.E.

*Breakage of locomotive coupling-rods while the wheels are slipping may be associated with resonant angular vibrations of the wheel-and-coupling-rod system. Failure is usually by bending in a horizontal plane in a manner consistent with either instability of the rod as a strut or yielding under bending induced by compressive load applied at the edges of the bearing bushes.*

At various times in the past there have been breakages of coupling-rods on locomotives whilst the driving wheels were slipping, and it does not appear that a completely satisfactory explanation has been found. The first obvious suggestion is that if the peripheral speed of the wheels when slipping is much higher than the highest running speed of the locomotive the centrifugal forces on the rods may be much greater than the designer anticipated, and this, in conjunction with the fact that the axial force in the rod is a higher proportion of the piston load than when the driving wheels are gripping, could explain failure by bending in the vertical plane. In actual fact most failures of coupling-rods have been by bending in the horizontal plane.

As the cross-section of any conventional coupling-rod is tall and narrow, the moment of resistance to lateral bending and therefore to lateral buckling under compressive load is much less than that for vertical bending. An apparent offset tc this difference is the fact that the bearing of coupling-rod bush on its pin may offer an approximation to the "fixed-end" condition for lateral bending, whereas the end condition for vertical bending is that of pin-jointing or a very close approximation to it.



Dimensions of cross section of coupling rod

The effect of heavy compressive load in a rod is, however, to take up clearances in axleboxes and to bend the crankpins in such a way that their outer ends are further apart than their sections at the faces of the crank bosses so that for lateral bending the end conditions may approximate to those of point loading on a line offset from the axis of the rod and tending to induce outward bending of the rod in the manner that is usually found in failure. With normal dimensions of a locomotive coupling-rod the stress due to lateral bending near the middle of the length can reach the yield point of low-carbon steel under a smaller offset load than would suffice to cause lateral buckling by Eulerian instability. Similarly, the centrifugal loading that brings the maximum bending stresses up to the yield point makes little difference to the axial load required to cause vertical buckling. In other words, horizontal bending by non-axial loading is a more likely cause of failure than is instability under axial load.

If the steam is allowed full access to the steam chests when the wheels are slipping, the loads in the coupling-rods may be greater than when the wheels are gripping, because then the driving wheels are able to transmit a high proportion of the torque produced by piston thrust, leaving the rest to be divided between the coupling-rods mounted on the driving crankpins. When the wheels are slipping the frictional resistances at the rails are low and much of the crankpin effort is transmitted by the coupling-rods to the coupled wheels, giving them the same angular acceleration as the driving wheels. The worst condition is the running of the leading coupled wheels, whilst slipping, on to sanded rails, because the resulting frictional torque causes angular retardation of all the coupled wheels and the coupling-rods mounted on the leading coupled wheels must transmit the equivalent of the frictional torque divided by the ratio of the total moment of inertia of all the coupled wheels to the same amount less that of the leading coupled wheels. Similarly the steam loads on the driving crankpins are divided between the coupling-rods according to the moments of inertia of wheel and axle assemblies.

To illustrate this, consideration may be given to the case of a six-coupled locomotive with cylinders applying a torque $T$ to the middle axle. Let the frictional torque applied by sanded rail to the leading coupled wheels be $F$, the frictional torque on each of the other axles being $f$. Now if the moment of inertia of each wheel and axle assembly about its axis be $I$, the common angular acceleration is

$$\frac{T-F-2f}{3I}.$$

The total torque on the leading coupled wheels is therefore

$$\frac{T-F-2f}{3}$$

and as the tyre applies $-F$, the torque applied by the coupling-rods is

$$\frac{T-F-2f}{3}-(-F)=\frac{T}{3}+\frac{2}{3}(F-f).$$

If one crank is vertical this torque is applied by the load in one coupling-rod alone. The

axial load on a leading coupling-rod is thus increased by any excess of frictional resistance at the leading tyres over that at the other tyres. Some confirmation is thus afforded of the natural feeling that the running of slipping wheels on to a sanded rail sets up heavy loading in axles and coupling-rods and some light is thrown on the fact that rod failure when slipping is nearly always in a leading rod. The actual effect is less serious than might at first appear, because the coefficient of friction at high rubbing speed is low and also because the steam load on the crankpin is low at high rotational speed unless that high speed is the result of slipping whilst pulling hard at low track speed. An adequate safeguard against breakage of a rod would appear to be a capacity to take a suddenly applied non-axial load (at the edges of the bushes) large enough to slip all the wheels in the smaller of the two groups that the rod connects. It would be interesting to know whether there is any recorded failure of a rod of that load capacity.

Breakages of coupling-rods when rail friction is low because of high rubbing speed suggest that they arise from conditions not particularly concerned with friction. As the loads in the coupling-rod are vibratory in character, it is natural to study the circumstances as an example of a vibration phenomenon. Three pairs of driving wheels, three axles and three pairs of coupling-rods form a system in which each wheel and axle may have angular vibration about a uniformly rotating reference plane under the influence of the elasticity of axles and coupling-rods. This system is subjected to cyclic torques exerted by steam on the crankpins and the loads in the coupling-rods may be many times as great as the piston loads if the externally applied torque has any simple harmonic component of frequency equal to that of a natural angular vibration of the system. To investigate this possibility, it is first necessary to estimate the natural frequencies of angular vibration of a typical system in order to ascertain whether the condition of resonance occurs at slipping speeds likely to be attained.

### Example

In the following, a system composed of six wheels on three equally spaced axles is considered. Coupling-rods are used to connect the wheels. Crankpins in the two wheels of a pair are in perpendicular axial planes.

Let

$A$=cross-sectional area of coupling-rod.
$c$=crank-throw.
$d$=diameter of axle.
$E$=Young's modulus.
$i_h$=second moment of area of cross-section of coupling-rod about horizontal axis containing the centroid.
$i_v$=ditto about vertical axis.
$K=AEc^2/s$.
$L$=torsional stiffness of axle.
$s$=spacing of axles (length of coupling-rod).
$w$=length of axle between inner faces of wheel bosses.

Because of the symmetry of the system, the central wheel-and-axle assembly is a node in certain modes of vibration. The effective stiffness of each coupling-rod depends on the crank angle and so the system is not symmetrical about the longitudinal central plane except when the cranks make angles of 45 deg. with the horizontal or except for modes of vibration that leave the rods unloaded and these need not be considered here.

The mode that is most important is that in which the leading wheels have angular vibration relative to the central wheels under the influence of the elasticity of the leading coupling-rods and the leading axle. The central axle does not act as an elastic element as symmetry demands that both its wheels have zero amplitude of angular vibration. The angular vibrations of the rear wheels are equal and opposite to those of the leading wheels.

### Effective Stiffness of Coupling-Rod

Let

$\theta$=angle between crank and vertical.
$P$=axial load in rod.

Then

Torque on axle $=Pc\cos\theta$.

Change in length of rod for load $P=\frac{P}{A}\frac{s}{E}$.

Hence relative angular displacement of axles for load $P$

$$=\frac{P}{A}\frac{s}{E}\frac{\sec\theta}{c}.$$

Equivalent torsional stiffness of rod

$$=\frac{\text{Torque}}{\text{Angle}}=AE\frac{c^2}{s}\cos^2\theta.$$

The stiffness varies with crank-angle and so the natural vibrations of the system are not simple harmonic, although for the present purpose they may approximate sufficiently closely to simple harmonic character.

A preliminary investigation has shown that the most serious resonant vibration at any probable rotational speed is one of the fourth order (i.e. one whose frequency is four times that of rotation of the wheels) for its frequency is that of the piston impulses which, in a two-cylinder engine, occur four times per revolution of the wheels.

In a vibration of this type, one cycle is completed in a quarter-revolution and it is therefore necessary to consider the variation of equivalent torsional stiffness of each rod during a quarter-revolution.

Writing $\frac{AEc^2}{s}=K$, assuming the wheels to have mean angular velocity $\omega$, and measuring time from an instant when crank No. 1 is vertical, the instantaneous equivalent torsional stiffness of rod No. 1 is :

$K\cos^2\omega t$ and the mean stiffness from $t=0$ to $t=\frac{\pi}{2\omega}$ $\left(\text{i.e. from }\theta=0\text{ to }\theta=\frac{\pi}{2}\right)$ is

$$\frac{2\omega}{\pi}\int_0^{\pi/2\omega}K\cos^2\omega t\,dt=\tfrac{1}{2}K.$$

Similarly the instantaneous equivalent torsional stiffness of rod No. 2 is $K\sin^2\omega t$ and the mean stiffness from $t=0$ to $t=\frac{\pi}{2\omega}$ is also $\frac{1}{2}K$.

The mean equivalent stiffness is the same for both rods for a quarter-revolution only when it begins with one crank vertical. In general the mean stiffness during a quarter-revolution is

$$\frac{2\omega}{\pi}\int_\alpha^{\alpha+\pi/2}K\cos^2\theta\,d\theta=K\left(\tfrac{1}{2}-\frac{\sin 2\alpha}{\pi}\right)$$

where $\alpha$ is the inclination of the crank to the vertical at the beginning of the quarter-revolution.

It may be noted in passing that the instantaneous sum of the stiffnesses is always $K$, so that if the torsional stiffness of the axle were very large the common angular vibration of the wheels would be simple harmonic.

### Natural Angular Vibrations with Middle Axle as Node

Natural vibrations can thus occur during quarter-revolutions between successive coincidences of cranks with the vertical and, although they are not exactly simple harmonic, their frequency is unlikely to differ greatly from that of simple harmonic vibrations under constant stiffness, equal to the mean value of the actual stiffness.

Let time be measured from the instant at which crank No. 1 is vertically above the axle. Let the instantaneous angular displacements of the leading wheels from the uniformly rotary angular position corresponding to that of the central axle be $\lambda_1$ and $\lambda_2$.

Axle torque tending to increase $\lambda_1=\frac{CJ}{w}(\lambda_2-\lambda_1)$.

Where $C$=Modulus of rigidity of axle material.

$$J=\frac{\pi d^4}{32}.$$

Coupling-rod torque tending to decrease

$\lambda_1=\lambda_1 K\cos^2\theta$ (instantaneously)
or $\frac{1}{2}\lambda_1 K$ (mean).

Then if $I$ be the moment of inertia of one wheel about its axis of rotation,

$$\frac{Id^2\lambda_1}{dt^2}=\frac{CJ}{w}(\lambda_2-\lambda_1)-\tfrac{1}{2}\lambda_1 K$$

$$\text{or }\left[D^2+\frac{1}{I}\left(L+\frac{K}{2}\right)\right]\lambda_1=\frac{L}{I}\lambda_2,$$

where $D^2$ indicates the second differential coefficient with respect to $t$, and $L=\frac{CJ}{w}$.

Similarly

$$\left[D^2+\frac{1}{I}\left(L+\frac{K}{2}\right)\right]\lambda_2=\frac{L}{I}\lambda_1.$$

Multiplying,

$$\left[D^2+\frac{1}{I}\left(L+\frac{K}{2}\right)\right]\left[D^2+\frac{1}{I}\left(L+\frac{K}{2}\right)\right]=\left(\frac{L}{I}\right)^2,$$

$$\text{or }\ D^4+\frac{(K+2L)}{I}D^2+\frac{KL}{I^2}+\frac{K^2}{4I^2}=0.$$

Whence

$$D^2=-\frac{K+2L}{2I}\pm\frac{1}{2I}\sqrt{[(K+2L)^2-4KL-K^2]}$$

$$=-\frac{K}{2I}\text{ or }-\frac{K+4L}{2I}.$$

Hence

$$\lambda_1=P\sin nt+Q\cos nt,$$

where $P$ and $Q$ are arbitrary and

$$n=\sqrt{\frac{K}{2I}}\text{ or }\sqrt{\frac{K+4L}{2I}}.$$

The lower value of $n$ is independent of $L$ and must therefore correspond to a mode of vibration in which the axles have no vibratory twist, i.e. the two wheels on any axle have angular vibrations in phase.

The higher value of $n$ applies to the mode of vibration in which the two wheels on each axle have opposite vibratory motions.

### Natural Angular Vibrations with Middle Axle as Antinode

The system under discussion has seven modes of vibration, and the calculation of the frequencies for modes of vibration in which the middle axle is not a node is in general complicated.

One case is however analysed quite simply and that is the one in which the axles suffer no vibratory twist, while the leading and trailing wheels have identical angular vibrations in phase with each other and antiphased to those of the middle axle. This vibratory

system may be divided into quarters, each composed of a wheel on an outer axle, a coupling-rod and half the wheel on the middle axle. In this mode, there is a node in each coupling-rod, at a section distant from the outer axle by an amount equal to one-third of the rod length. The natural frequency is equal to that of a system composed of a wheel and a coupling-rod similar to the actual rod but of only one-third its length. This is comparable with the mode that gives the lower of the two natural frequencies already discussed and its natural frequency is $\sqrt{3}$ times as high.

### Critical Speeds for Wheel-Axle-Rod Vibrations

The values of $n$ for the three vibration modes discussed previously are :

$$\sqrt{\left[\frac{1}{2}\frac{K}{I}\right]},\ \sqrt{\left[\frac{1}{2}\frac{K}{I}\left(1+\frac{4L}{K}\right)\right]} \text{ and } \sqrt{\left[\frac{3}{2}\frac{K}{I}\right]}$$

and the frequencies are these multiplied by $1/2\pi$.

The angular velocity of the wheels at a critical speed of order $m$ is equal to $1/m$ times the value of $n$ for the natural frequency concerned, and so the fourth order critical speeds in revolutions per unit time are

$$\frac{1}{8\pi}\sqrt{\left[\frac{1}{2}\frac{K}{I}\right]},\ \frac{1}{8\pi}\sqrt{\left[\frac{1}{2}\frac{K}{I}\left(1+\frac{4L}{K}\right)\right]}$$

$$\text{and } \frac{1}{8\pi}\sqrt{\left[\frac{3}{2}\frac{K}{I}\right]}.$$

The fourth order critical speeds for other modes of vibration are higher than these and in practical cases of six-coupled locomotives need not be considered. Indeed, the highest of these three is unlikely to be attained even when slipping badly at high road speed.

These three critical speeds are given in Table I for two locomotives of typical dimensions.

### Lateral Vibration of Coupling-Rod

The coupling-rod itself has several modes of lateral vibration between ends that are approximately pin-jointed. The lowest natural frequency of such a vibration of a steel rod is

$$0{\cdot}32\times10^6 k_v/s^2 \text{ (cycles per sec.)},$$

where $k_v$=radius of gyration (in) of cross-section about the axis that contains the centroid and is perpendicular to the plane of vibration. $s$=length of rod (in).

Because of the width of the coupling-rod bushes, the actual end conditions lie between those of a pin-joint and those of a " built-in " beam. As a result the natural frequency, and the associated critical speeds are somewhat higher than those corresponding to a frequency of $0{\cdot}32\times10^6 k_v/s^2$.

### Effect of Play at Joints

An effect of slackness between the coupling-rod bushes and the crankpins is to increase the period of any natural vibration by the time taken by the pin in moving from one extreme position to the other twice in a complete cycle. Thus if the amplitude of vibratory stress corresponds to a linear amplitude $h$ at the crankpin and if the phase velocity of the vibration is $n$, the period of the natural vibration without slackness is $\frac{2\pi}{n}$. The linear velocity at the instant of zero vibration stress is $hn$ and the time taken in twice crossing a clearance $z$ is therefore $\frac{2z}{hn}$. The period of vibration with slackness is thus $\frac{2}{n}\left(\pi+\frac{z}{h}\right)$.

In a rod 7ft long (for example) a vibratory stress of 10 tons per square inch corresponds to an extension of $\frac{10}{13{,}000}\times84=0{\cdot}065$in. A play of (say) 0·1in at the crankpin would therefore increase the period of natural vibration in the ratio $\left(\pi+\frac{0{\cdot}1}{0{\cdot}065}\right)\Big/\pi=1{\cdot}49$ or, in other words it would multiply the corresponding critical speed by 0·67.

If the vibratory stress were 20 tons per square inch the effect of play would be to multiply the corresponding critical speed by $\pi\Big/\left(\pi+\frac{0{\cdot}1}{0{\cdot}13}\right)=0{\cdot}8$.

The critical speed thus depends on the magnitude of the vibratory stress which in turn depends on the magnitude of the vibratory forces applied to the system. This characteristic and the damping associated with impacts as the clearances are taken up twice per cycle make the maximum magnification possible in such a system less than the maximum for harmonic vibrations in the same system with no slack joints.

So far as vibratory rod-stresses at resonance are concerned, a locomotive with considerable play at the coupling-rod pins is likely to be safer than with fine clearances, although the latter are of course more satisfactory in normal running.

### Damping of Resonant Vibration

The numerical examples given later show that a critical speed for angular vibration of coupled-wheel assemblies may lie within the rotational speed range of the wheels in normal running. It may therefore be asked why coupling-rod failures are not frequent if resonant vibration may produce dangerous stresses.

A possible answer to this is that, so long as the wheels are not obviously slipping on the rails, friction at the points of contact dissipates vibration energy when resonant angular vibration causes small alternating slips to take place and the consequent alternating frictional forces limit the vibratory loads in the system to a small multiple of the extreme forces that excite the vibration. In other words the system has strong friction damping so long as the relative motion of tyre and rail is oscillatory about a mean condition of no slip. Friction may in fact prohibit vibratory motion altogether.

On the other hand, when the wheels are continuously slipping, with mean rubbing speed that is high compared with the vibratory speed of the tyre, the frictional force is constant in direction and is not perceptibly changed in magnitude by the very small proportional speed variations caused by resonant vibration. A constant resisting force does not restrain resonant vibrations and therefore, when the wheels are slipping, the system is damped only by hysteresis in the stressed material, by viscous resistances in oil films and by loss of energy due to impact on taking up clearances. The dynamic magnification of load in such a system may be of the order of 40 and this is enough to induce compressive loads beyond the capacity of the coupling-rods.

### Numerical Examples

The figures in Tables I and II are approximately those of two classes of six-coupled locomotives frequently employed on fast passenger trains. The main distinction between their wheel-axle-rod system is that " I "-section coupling-rods are used in the first case and rectangular-section rods in the other. There have been breakages of the " I "-section rods in the first case, and the use of the rectangular section in the L.M.S. class " 5 " may be traced back to its adoption over forty years ago in rods to replace " I "-section rods broken by the G.W.R. four-cylinder 4–4–2 " North Star " when slipping. The rectangular section was afterwards standardised on the G.W.R. and much later by Sir William Stanier on the L.M.S. Later still there was a reversion to " I "-section rods on the more recently-built examples of L.M.S. class " 5 " 4–6–0. There have been failures of these rods on locomotives when slipping whilst running fast through tunnels.

Table I

| Reference No. | 1 | 2 |
|---|---|---|
| Approximate equivalent | B.R. class " 7 " 4–6–2 | L.M.S. class " 5 " 4–6–0 |
| Diameter of wheel (in) | 74 | 72 |
| Crank throw $c$ (in) | 14 | 14 |
| Axle diameter $d$ (in) | 8* | 8 |
| Axle length $w$ (in) | 52 | 52 |
| Rod length $s$ (in) | 84 | 84 |
| Rod dimensions : | | |
| $a$ (in) | 2·75 | 1·75 |
| $b$ (in) | 4·75 | 5·25 |
| $x$ (in) | 0·75 | 1·75 |
| $y$ (in) | 3·75 | 0 |
| $z$ (in) | 3·0 | 3·5 |
| Area $A$ (sq. in) | 5·56 | 9·2 |
| $I_a$ (in$^4$) | 15·8 | 21·0 |
| $I_e$ (in$^4$) | 1·84 | 2·3 |
| Radius of gyration : | | |
| $k_a$ (in) | 1·69 | 1·51 |
| $k_e$ (in) | 0·575 | 0·5 |
| Stiffness $K$ (lb-in per radian) | $390\times10^6$ | $645\times10^6$ |
| Stiffness $L$ (lb-in per radian) | $83{\cdot}5\times10^6$ | $92{\cdot}5\times10^6$ |
| Moment of inertia of one wheel (lb-in sec$^2$) | 8500 | 7900 |
| Natural frequency (c/s) : | | |
| Wheel-axle-rod (angular) | 24·2 32·8 42·0 | 32·2 40·3 55·7 |
| Rod laterally (linear) | 26 | 22·6 |
| Critical rim speeds (m.p.h.) for 4th order vibrations of : | | |
| Wheel-axle-rod (angular) | 80 108 138 | 103 130 178 |
| Rod laterally (linear) | 86 | 73 |

* 4½in bore.

Table II

| Reference No. | 1 | 2 |
|---|---|---|
| Load (tons) on leading coupled axle | 20·5 | 17·75 |
| Maximum rod load (tons) that may be necessary to cause slip with $\mu=0{\cdot}3$ in static condition | 16·3 | 13·7 |
| Section modulus (in$^3$) of rod for lateral bending | 1·34 | 2·62 |
| Maximum bending stress (tons per sq. in) produced by maximum rod load acting at edges of bushes | 18·2 | 9·1 |
| Crippling load (tons) (Euler) | 33·4 | 41·5 |
| Factor of safety on Euler crippling load | 2 | 3 |
| Offset rod load (tons) to produce bending stress of 20 tons per sq. in | 18 | 30 |

The figures under Reference 1 show that resonant vibration of the wheel-axle-rod system may be set up at a wheel-rim speed of 80 m.p.h. and this might well be attained while slipping at a track speed of 60 to 70 m.p.h. A critical speed for lateral vibration of the rods occurs at 86 m.p.h. and (allowing for unavoidable uncertainties in the figures) this is near enough to 80 m.p.h. to suggest that the rods might be subjected to loads intensified by two different types of resonance at the same time. These figures at least suggest that slipping of any engine of this class at a rim speed of about 80 m.p.h. should be checked as quickly as possible.

Reference 2 seems considerably safer as the lower fourth order critical speed for angular vibration is 103 m.p.h., which is well outside the normal running range, and the critical speed for lateral vibration of the rod is well removed from it. Replacement of the " I "-section rod in Reference 1 by the rectangular-section rod in Reference 2 would

clearly reduce the risk of resonant vibration. Furthermore, Table II shows that although the Eulerian crippling load of the rectangular rod is 24 per cent higher than that of the other, the advantage in respect of offset load required to produce any specified bending stress is in the ratio of 30 to 18, i.e. 67 per cent increase. The main factor here is the much higher section modulus for lateral bending. The advantages of this particular section have to be set against greater weight (in the ratio of about 9·2 to 5·56 or some 60 per cent extra), but probably include lower cost.

It should be mentioned that during special slipping tests on oiled rails a class "5" locomotive attained wheel-rim speeds between 100 and 110 m.p.h. without coupling-rod breakage and this raises doubt as to whether resonant vibrations occurred or, if they did occur, whether they were dangerous. It may be that the piston forces that sufficed to keep the wheels slipping on oiled rails did not generate rod stresses high enough to cause failure in the period of the test.

It must be noted that the advantage conferred by the rectangular section rod is not peculiar to that geometrical form. To raise the natural frequency for wheel-axle-rod vibration, the cross-sectional area of the rod must be increased regardless of the shape of the section. It may well happen that the cross-sectional area necessary to produce a suitable natural frequency will give adequate section moduli and second moments of area when disposed as a rectangle, and the "I"-section is then an unwarrantably expensive luxury.

### Other Factors

Errors in the relative angular positions of crank-pins ("quartering errors") can induce high coupling-rod loads at certain crank positions in every revolution of the driving wheels. Inadequate grip of wheel-hubs on axles may permit rotational slippage under a few applications of high rod-load at resonance; this produces a quartering error that may cause rod failure by fatigue under repeated high loading in subsequent running.

The running of slipping wheels on to well-sanded rails may induce coupling-rod loads great enough to cause failure if the rod has not been designed to take the full load possible in the worst static condition with a factor of 2 to cover the dynamic effect of sudden application of the maximum frictional force to the tyres of the leading coupled wheels.

### Conclusions

(1) Resonant angular vibration of wheel, axle and coupling-rod assemblies of conventional dimensions may correspond to a fourth-order critical speed in the running range of a fast passenger train.

(2) It is possible for heavy vibratory forces to be induced in the rods when the wheels are slipping with rim speed at or near the critical speed.

(3) Coupling-rods should be preferably designed to bring the critical speed above 100 m.p.h.

(4) Violent slipping should be checked by the driver as quickly as possible but without using sand.

(5) Coupling-rods should be designed so that the Euler crippling load for lateral buckling is at least two and a half times the load that the rod must transmit to cause slipping of the smaller of the groups of wheels it connects under maximum adhesion weight and with coefficient of friction equal to 0·3.

(6) Coupling-rod bushes should have minimum width consistent with acceptable bearing pressure.

## Dounreay Fast Reactor Project*

J. W. KENDALL and T. M. FRY†

The fundamental reason for developing the fast reactor for the generation of industrial power was that it seemed capable of much more efficient utilisation of uranium fuel than a system based on thermal fission. The energy content of U238 is little different from that of U235, but when natural uranium is fed into a thermal system all but a few per cent, depleted in its content of U235, must be thrown on to the ash heap. The need to conserve uranium may not be great at present, but ultimately the possibility, afforded by the fast system, of using almost all of the uranium should be most attractive.

A fast neutron chain reaction cannot be sustained in uranium of natural enrichment. The core of the reactor must be charged with a much higher proportion of fissile material, either U235 or Pu239, than is present in natural uranium. The cost of fissile material is measured in thousands of pounds per kilogram, so that the initial charge represents a substantial capital investment. If it is to be used as a "catalyst" for deriving power from U238, each kilogram of fissile material must yield hundreds of kilowatts of electricity. This sets one objective for development; we cannot consider the fast reactor as an economic source of power until ratings of this order have been demonstrated. Moreover, this rating must be based on the total fissile investment in the whole system, including processing plants, and not just that in the reactor.

The second target for development is outlet temperature. The heat produced in a power reactor must be at a sufficiently high temperature so that it can be converted to power with useful efficiency.

Ideally one would like to feed natural uranium into the reactor and remove the fission products continuously. In practice it will be necessary to remove the fuel periodically for purification and refabrication, an expensive process which also increases the investment of fissile material needed to operate the system. This sets the third criterion of successful operation of a fast reactor; the cost of processing the fuel must not be excessive. If the process is expensive or takes a long time the fuel must produce a lot of heat before processing is necessary. It is difficult to give an exact figure, but, with the processes at present envisaged, a burn-up of the order of 10 per cent of the fissile material is probably needed. At the ratings required this would take a few months' irradiation in the reactor.

Finally, if the reactor is to be sited in the United Kingdom, it must be safe.

At Dounreay, on the north coast of Scotland, the United Kingdom Atomic Energy Authority is building a fast reactor. The project is essentially experimental, for no engineering experience is available on which to design a core with the rating, outlet temperature and burn-up required. The best way to get this knowledge seems to be to build a plant having the most flexible design that can be achieved. As failures are replaced by better components it is hoped to demonstrate that a fast reactor can be a sound economic proposition for the production of industrial power.

At this point mention must be made of the achievement in the United States of the production of electrical power from a fast reactor, the EBR, as long ago as December, 1951. While this has shown that many of the technical problems can be overcome, a much bigger output must be attained if the power is to be produced at an economic cost. While not going the whole way to that suitable for a full-scale generating station, a core size has been selected for the Dounreay reactor, about 2ft in diameter and 2ft long, from which it should be possible to extrapolate to a larger reactor.

The plant (Fig. 1) will consist of a pot through which enough coolant can be pumped to remove more than 60MW of heat. In this pot tubes, plates and other structures can be placed to support the blanket and core of the reactor. If experience shows that the first designs are unsatisfactory, the contents of the pot can be removed and a fresh start made.

If high heat output is to be obtained a coolant of high specific heat and high thermal conductivity is needed because of the small core size, while a low vapour pressure is a great advantage. These considerations led to the choice of liquid sodium with possibly some addition of potassium to lower the freezing point. Small-scale experimental experience of these coolants was available when this choice was made.

The reactor is going to cost some millions of pounds, and its core will contain a substantial quantity of fissile material. It therefore represents an investment which must not be lost as the result of an accident. Because of the persistence of heat release after reactor shutdown, it is essential that a supply of coolant to the core shall be guaranteed at all times. The core of the fast reactor is so highly rated that it would quickly rise to melting point if the coolant were removed. The design of the cooling circuits (Fig 2) has therefore been prepared with this in mind.

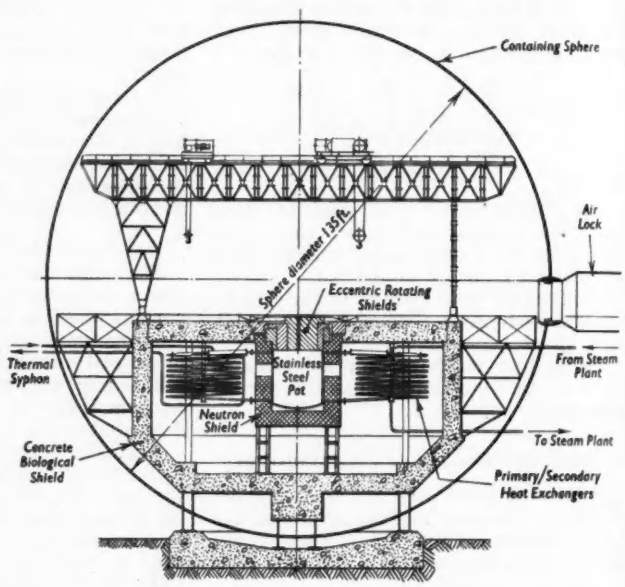



**Fig. 1—Arrangement of Dounreay reactor**

### Coolant Circuits

The circuits will be made from stainless steel throughout. This is a good material for high working temperatures and also helps in getting a clean oxide-free circuit. The design and method of fabrication has been taken over from that of highly radioactive chemical plant. Here a stainless steel plant, containing nitric acid and other corrosive chemicals, had to be built to such a standard that leaks would not occur. By the exclusive use of butt welding and radiographic inspection of almost every inch of weld, this requirement was met. The pot and the pipework forming the primary circuit of the fast reactor can be made equally reliable. All valves are excluded from the design and there will be no connected dump tanks into which the coolant might accidentally be transferred.

Twenty-four parallel loops (Fig. 3), each comprising two separate heat exchanger sections and an electromagnetic pump, will complete the

* Abstract. Paper presented at International Conference on Peaceful Uses of Atomic Energy, Geneva, August 8–20th.

† U.K. Atomic Energy Authority.

primary circuit. The lower part of each loop will be jacketed with an outer tube, through which the secondary coolant will be pumped. Above this will be a short flattened section, against which are pressed the electromagnetic windings. At the top will be another jacketed heat exchange section, providing thermo-syphonic rejection of shut-down heat to air in the event of total failure of electrical supplies. Twenty of the loops feed the core from a common header space at the top of the pot, while four more provide coolant for the blanket.

Adhering to the principle that the removal of heat must be maintained, multiple secondary and subsequent heat-rejection circuits will be provided. Even the power supplies will be separated. Electrical power for the pumps will be provided by diesel generators, each of which will be connected to only two of the primary pumps and their subsidiary circuits. Thus, the failure of one generator will only cut out one-tenth of the pumps. The flow through the core will fall by a rather larger fraction because some coolant will flow in the wrong direction through the ineffective pumps. Even so, the reduction in flow will not be by a dangerously large amount.

Sodium or sodium-potassium alloy will be used for the secondary coolant. On grounds of safety it is argued that the secondary coolant must be chemically inert to the primary coolant, which rules out water. The secondary coolant will carry the heat to a boiler-house for steam raising. As there will be no radioactivity involved, a reaction between sodium and water in this part of the plant would not involve widespread hazard. Waste heat will be disposed of by a sea-water cooled condenser.

The secondary coolant must not become radioactive, so a neutron shield is needed between the pot and the heat exchangers. This shield can also perform another function. Measurements of fission rate must be obtained even when the reactor is shut down. In fact, it is especially important to make measurements when the reactor is not generating appreciable quantities of heat, for it is then that reactor accidents are likely to happen. A detector of thermal neutrons, placed in a mass of moderating material outside the pot, should combine sensitivity with accessibility.

The neutron shield consists of graphite stacked around the pot to a thickness of 4ft. Most of the graphite will contain enough boron to absorb the neutrons when they have slowed down. In a belt at the level of the core, pure graphite will be used for all but the outermost layer. In this region a high density of thermal neutrons will build up, making it possible to determine the fission rate down to very low levels. To ensure that this rate can never fall below the minimum observable, a neutron source will be placed in the reactor.

The advantage, which it is hoped will be gained by the use of borated graphite for absorbing neutrons, is that very much less long-lived activity will be induced than if steel were used. This should simplify the problems of dismantling the neutron shield if ever it should be necessary. The graphite will be kept hot to reduce radiation damage.

The graphite and the pot will be supported on a steel structure standing on a concrete base, which forms part of the biological shielding. This will consist of a concrete bowl of outside diameter almost 90ft, 45ft high, with a minimum thickness of 5ft. These dimensions are determined by the size of the heat exchangers and the activation of the coolant. The roof slab, which has a central hole 20ft in diameter, will be supported on a ring of vertical columns. These introduce complications because they will stand in the space to be occupied by heat-exchange equipment, but the slab is too large to be supported round its rim without introducing a prohibitive concentration of reinforcement near the centre. The heat exchangers will hang from the roof slab.

Pure sodium is a better heat transfer medium than the alloy and is much cheaper but, if it is to be used, the entire primary circuit must be kept above the freezing point of sodium so that blockages cannot occur. The whole of the vault will, therefore, be made into a hot-box, with air heaters. The concrete and the columns supporting the roof will be lagged and air cooled. In the early stages of operating sodium-potassium alloy will be used so that the vault will be accessible when the activity of the coolant has died away after shut-down.

This is a reactor which may require alteration and development before its operation is entirely satisfactory. For this reason there is to be a large hole in the roof slab, closed with removable shielding. It should be possible to remove the equipment from the vault through this hole. In the centre, the top of the pot will be closed by a thick plug of shielding in the form of eccentric cylinders with liquid lute seals, which can be rotated to align the charge machine over the inside of the pot. During operation the plug will be sealed mechanically against the coolant pressure with an intervening gas blanket.

Following the example of the Knolls Atomic Power Laboratory at West Milton, the Dounreay reactor will be enclosed in a steel sphere 135ft in diameter and about 1in thick.

## Safety Considerations

A theoretical examination of the problem of the safety of fast reactors has been made and the magnitude of the explosion that would occur, if the reactivity were rapidly increased beyond prompt critical, has been estimated. It is doubtful whether a pressure vessel of practicable dimensions could contain such an explosion. It is confidently believed, however, that the danger can be eliminated by suitable design of the control system and of the core itself.

Although an explosion will not occur, one cannot be quite sure that there will be no sort of plant failure which could result in fission products escaping. With something like 100 million curies in the core, an escape of more than a few per cent would be a very substantial hazard over a wide area. The sphere has, therefore, been designed to contain these fission products in the very improbable event of their escape from the core.

The liquid metal coolant brings with it a risk of fire. To reduce this risk no significant quantity of water will be allowed inside the sphere, but there will be about 13 tons of oxygen in the air. The vessel is not designed to contain the pressure that would develop if all this oxygen were to combine instantaneously with sodium.

Sodium is a poor fuel. Like other fuels, it reacts with air in the vapour phase. Its high boiling point, 883 deg. Cent., and high latent heat of vaporisation, 1 kilocalorie per gramme, make it slow to burn in air. The heat of combustion is only 2 kilocalories per gramme, so that half of this must be fed back to vaporise a further supply of fuel for the fire. The higher thermal conductivity tends to conduct heat away from the burning surface, which is quickly covered with an insulating layer of oxide. A sodium fire will, therefore, not be self-sustaining at a high rate of combustion. The heat necessary for vaporisation must be derived from some other source. In this case the only source available would be the radioactive decay of fission products in the reactor fuel.

## Conclusions

Conditions may be envisaged in which it has ceased to be possible to extract heat from inside the sphere. The temperature of the reactor rises. The neutron reaction closes down, but the emission of heat from the decay of fission products continues. In the worst case all this heat might go to evaporating sodium. The burning of the sodium vapour produces twice the amount of heat absorbed in vaporisation. All this heat might be transferred to the air. This, in turn, would transfer heat, by natural convection, to the steel pressure vessel, which would be cooled by the outer air. On these assumptions the air would reach a maximum temperature of 340 deg. Cent. and a maximum pressure of 16 lb per square inch some fifteen minutes after the fire started. Making some additional allowance for barometric variation and so on, the design figure for the maximum internal working pressure of the sphere has been taken to be 18 lb per square inch.

The internal pressure, is not, however, the only criterion to be considered in designing the sphere. After the reaction had gone to completion and all the oxygen in the sphere had been consumed, the temperature would eventually fall, leaving a partial vacuum inside. The removal of the oxygen would leave an external pressure of 3 lb per square inch. The pressure at which it would begin to buckle depends on the uniformity of the steel shell. The most pessimistic estimate is that, at 5 lb per square inch external pressure, a shallow dimple some 18ft in diameter would appear at the top. This would not raise stresses in the steel greater than 1 ton per square inch. The most unfavourable combination of circumstances could not impose a greater pressure on it than this.

Because reliance is placed on heat transfer from the outside to dispose of heat in the event of an accident, no lagging will be provided on the outside of the sphere and water will be piped to the top so that it can be pumped over the outer surface to assist the removal of heat if need be.

Prudence dictates that, in the design of such a novel and highly rated reactor, extreme precautions be taken. It is hoped that, when experience in fast reactors has been gained, they will provide a safe and enduring source of power for mankind.

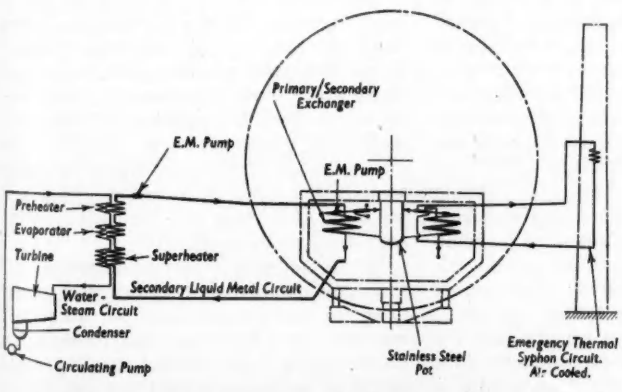



Fig. 2—Diagrammatic arrangement of liquid metal and steam circuits of Dounreay fast reactor

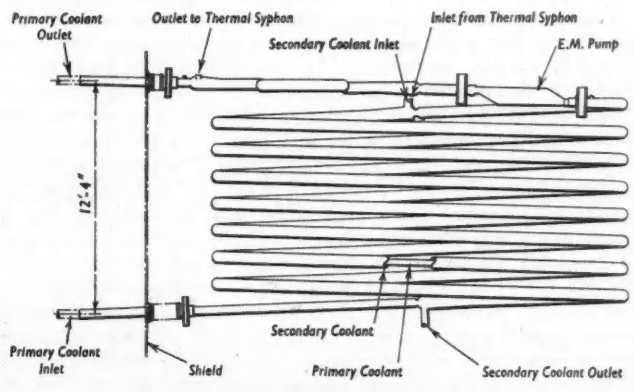



Fig. 3—Outline of a primary/secondary heat exchanger loop

# LETTERS AND LITERATURE

## Letters to the Editor

*(We do not hold ourselves responsible for the opinions of our correspondents)*

### RESILIENCE OF A GYMNASIUM FLOOR

SIR,—I am grateful to Dr. Williams for his letter which you published on July 22nd, because he sets out the case for the resilient floor much more clearly than its other advocates have been able to do. I have waited for other comments and until I could obtain the quantitative data given below. We are, I think, agreed that the resilience of the legs gives complete protection from shock to the spine, the vital organs and the head—as Nature intended. The yield of the floor, which we measured as 0·03in when a 150 lb boy jumped from 3ft 6in, is so small that it can have no significance in this matter. Dr. Williams does feel, however, that the yield of the floor may be valuable in reducing foot shock when the ball of the foot strikes the floor with little muscular elasticity to absorb the shock. The elastic action of the foot arch and the ankle will protect the rear part of the foot from shock as the heels will not normally hit the ground. Shock is therefore confined to the toe half of the foot and this weighs about 1 lb for each foot.

The resilient floor is formed of hard wood planking $\frac{7}{8}$in thick with 3in by 2in joists 12in apart. These joists are carried on rubber pads which rest on the concrete and are spaced at about 4ft intervals. The weight of the floor above the rubber is therefore about 4 lb per square foot. It is difficult to say what area should be included in Dr. Williams's "generalised mass" $m_2$, but 10 square feet is perhaps a fair assumption by reason of the rigidity of the flooring itself. This 40-lb mass is so large by comparison with the 2-lb mass of the boy's two feet that, however soft the rubber pads may be, almost the whole of the kinetic energy of the feet will be absorbed in shock and matters are not appreciably worse if the floor is solid. The floor of a school gymnasium is used by children for periods of thirty to forty minutes. For nearly all landings rubber mats are used. They are of rubber sponge, about 1in thick, and have top and bottom faces of rubber sheet so that they absorb the horizontal as well as the vertical shock of whatever part of the body hits the mat. For running, the resilience of the floor will have less significance than in the landings, without mats, for which our tests were made. Only a small proportion of the forty-minute period is occupied in running. The school floors are not intended to be used for much longer periods by older men playing badminton and perhaps running on their heels more than they did when they were young. A dance floor is intended to respond to the synchronous movement of a large number of people and to pull them into accurate unison. It may also reduce fatigue during a long period. If playing badminton or dancing for long periods on a rigid floor does produce more fatigue than on a resilient floor, that is no evidence that a rigid gymnasium floor is likely to damage the children's feet. If there is any perceptible difference the rigid floor may teach the children to walk and run better on the surfaces they will meet in after life.

Estimates of cost prepared for me by a borough architect show that for 70ft by 40ft gymnasium floors, all of equally good surface, the difference in cost between Granwood, or other slightly resilient blocks, on concrete and two typical forms of resilient floor is about £500. That sum is considerably more than the cost of all the fixed and movable gymnastic apparatus supplied to a secondary modern school and about twice the cost of an acoustic ceiling which would make the teaching clearly audible. This is important, as the gymnasium is in many cases the school hall. Many men (and here the masculine embraces the feminine) do find that dancing or playing badminton on a rigid floor of very good surface does cause considerable fatigue and discomfort below the knee. This is not surprising, as the work which falls on the calf and foot muscles is so much greater than that on the rest of the muscular system and is far above normal. I find it very hard to get reliable evidence that the fatigue on a resilient floor is any less for truly comparative conditions and periods. If this difference can be established there is, as Dr. Williams suggests, an opening for a very interesting investigation in which the physiologist should certainly take part. Even if the preference for a resilient floor is purely psychological an extra £500 for a badminton court or a dance floor may be justified because the product of badminton and dancing is largely psychological.

The case for a resilient school gymnasium floor is very small indeed when there are so many better ways of spending—or saving—£500. T. R. CAVE-BROWN-CAVE

Southampton, August 24th.

### POLYTROPIC EFFICIENCY

SIR,—As Mr. E. A. Bruges goes off at the deep end on reading my letter in the issue of THE ENGINEER, dated July 8th, he must remember that quite a number of us work along at the shallow end and, even worse, are expected to produce results there. In the first place, however, let me state that I have not the slightest intention of interfering with the views and statements of a worker of the calibre of Mr. Bruges. Now we shallow-enders, amongst other matters, are concerned with the fortunes of a number of individuals, typical of whom could be, say, an average student at the Higher National standard. This individual has his deficiencies in class, but is not without a certain amount of commonsense outside and at his job, and is an expert in asking awkward questions. He is averse to using too much mathematics. On looking at Mr. Bruges's letter in the issue of THE ENGINEER dated April 22nd, I could well imagine this awkward fellow asking why bring in all the calculus when he could get the same result by dividing two well-known formulæ. Following this line of thought and envisaging further questions, I put down the formulæ I would use in the circumstances. They are over-simplifications and are intended to be so. I maintain it is better, by and large, to err by over-simplification than to over-elaborate in the attempt to get nearer the truth. Here I may say that I am quite aware that others may disagree with me entirely and that even the kelpies may snort. For the purpose, any attempt at rigid analysis is not suitable, anything that savours of "high-falutin" must be avoided. The formulæ so put down are in the form so beloved to our average student. They do not introduce anything new and are cut and dried in watertight compartments. But the student is not deluded. By now he does not accept everything he is told as gospel and is inclined to be sceptical of anything he does not understand. So the answers do for the time being until circumstances warrant their rejection. This is really not an uncommon feature of technical education, particularly where syllabuses are tight. We might quote, for instance, centrifugal force and the conventional theory of the nozzle, as examples of subjects which are introduced only to be discarded later. If, however, I have offended against the technical susceptibilities of Mr. Bruges I offer my apologies and, of course, will follow his advice to study the subject further. R. J. WOODROW

South Shields, August 23rd.

### GEOPHYSICAL PROSPECTING

SIR,—I was greatly interested to read the letters arising from my series of articles on the above subject. Whereas I readily agree with the correspondents that the diviner, or dowser as he is more frequently called, achieves sound and often spectacular results, I still stoutly maintain that the divining rod is not, and never can be, a geophysical instrument. There has never yet been a satisfactory scientific explanation of this curious phenomenon, and I feel that the most suitable analogy is that which can be drawn between thought reading and telecommunications. Whereas the former may work admirably, nobody in his senses would dream of using it as a reliable method of sending messages.

There may be some psychic explanation of dowsing, or possibly the fact that the human body is largely composed of water may have something to do with it on the basis of electrical conductivity.

My main argument is, and always will be, that nothing can take the place of sound geological knowledge supplemented by geophysical methods appropriate to the particular structure being investigated. Even to-day "wild-catting" is still undertaken, but it is an expensive business. When in Kuwait last December, I was told of a case where an oil rig was mounted on crawler tracks, and towed bodily across the desert by five track-laying tractors, after which a well was sunk more than 13,000ft deep, yet not a trace of oil was found! Yet only about 100 miles away there is one of the richest oilfields in the world at Burgan, with calculated reserves second only to those of the U.S.A.

Whereas all geophysical investigations will reveal the nature and arrangement of underlying strata, substances like oil, water and minerals are where you find them. If a diviner could have revealed the depth and extent of the Burgan oilfield he would to-day be an immensely rich man! ROLT HAMMOND

Henley-on-Thames, August 29th.

## Literature

*Elements of Servomechanism Theory.* By G. J. THALER. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 53s. 6d.

YET another book appears to swell the already bulging library of publications on the theory of servomechanisms. The author gives as his justification for this addition, the dubious necessity for a book on servomechanism theory for students who are not familiar with the operational calculus or complex variable theory. Whilst admitting that there may be some justifications for entering a subject such as this without a knowledge of operational calculus there appears to be little justification for omitting the elementary principles of complex variable theory which should be well within the mental capacity of one who, say, is capable of assimilating the manipulation of transfer functions.

Within the limitation of conception the book is well written and instructive. It begins with an introductory chapter in which concrete examples of particular systems are given to fix the topic in the student's mind. A chapter is devoted to stressing the inadequacy of physical reasoning and to discussing the choice of tools available, the conclusion being drawn that the differential equation is not an optimum approach. This, of course, depends very largely on the means available for solving the differential equation, and while it is true as far as most students are concerned, it certainly needs qualification as a general statement.

The third chapter discusses the transient analysis of servomechanisms, starting with a discussion of the various forms of forcing functions and going on to build up a servomechanism from its various components. The solution under various conditions of the constants is shown without indicating method and a discussion of the implication of the result given. Various feedback relationships are introduced and discussed and an interesting set of problems provided. The concept of a transfer function is introduced in the following chapter and again the author is to be commended on his choice of examples to illustrate the text and on the examples quoted at the end of the chapter. The subsequent chapter gives details of the polar and logarithmic method for presenting transfer function information with an indication of the field of application of various presentations.

The sixth chapter goes on to the actual analysis of single-loop systems and gives an account of Nyquist and Routh criteria, although much is left to the imagination as far as background theory is concerned. Systems are classified and discussed in terms of their steady state performance and the transfer function plot is used to determine the transient behaviour. From the synthesis point of view, a significant chapter on methods of meeting performance specifications is introduced and followed by a chapter on gain adjustment. Two very well written chapters follow, one on the series compensation of servomechanisms and the other on feedback compensation. Again, a very pleasing trend is towards the illustration of the discussion by many examples from the field of practical servomechanisms. In both cases the transfer function presentation favoured is the decibel *vs* phase-angle plot. Outside application in the school-room these two chapters should prove useful to the designer and might well be described as the highlight of the book. The remaining chapters are devoted to a discussion of more advanced topics such as multi-loop systems and more advanced analytical methods, such as the Root-locus method. The final chapter, devoted to non-linear systems, introduces the phase plane approach and concentrates more on identifying the problems than discussing a solution. To the student, this may serve as a warning that he has not yet reached the frontiers of knowledge, and that there still remains a lot to be known and learned outside the topics discussed in this book.

Any carefully written and produced book will always form an addition to the literature and any slightly different approach will probably add further to what may already be classed as a hackneyed subject. From this point of view, the book adds appreciably to the subject and may be of considerable use in undergraduate study, even if the undergraduate is familiar with the elements of the Laplace Transform and the simple manipulation of the complex variable.

*Manganese.* By A. H. SULLY. London: Butterworth's Scientific Publications, 88, Kingsway, W.C.2. Price 40s.

THIS is the third volume of the series "Metallurgy of the Rarer Metals" and deals with a metal which, although plentiful as a ferro-alloy, widely used in the steel industry for over 100 years and, thanks to the aluminothermic process, available in metallic form with varying amounts of impurities for the last 50 years, may still be claimed as one of the rarer metals. It has only recently been available in commercial quantities as a pure metal. Even so, the output goes entirely into alloys. This development has made possible great improvement in the quality of certain non-ferrous alloys which previously suffered owing to impurities which might be introduced with the manganese.

The first three chapters of the book deal with the occurrence of manganese ores, the production of ferro-manganese alloys and of pure manganese, and the conservation of manganese supplies, an important question in view of the essential need for manganese in the steel industry. Latest developments of electrolytic manganese production are fully described. A chapter on the physical properties of manganese gives a detailed account of all the known properties of the pure metal and this is followed by one on the constitution and properties of manganese alloys. These chapters are fully documented and between them contain well over 300 references. Unfortunately manganese is hard and brittle at room temperature. There are no satisfactory measurements of its mechanical properties, such as elastic modulus or tensile strength or even of its hardness. It exists in four allotropic modifications, three of which, of varying degrees of ductility, may occur, according to the treatment received, in specimens at room temperature. Electrolytic manganese, which is ductile as deposited, readily reverts to the brittle form which is stable at room temperature and can only be retained in the ductile condition by co-deposition with copper. The information given about the alloys of manganese is almost exclusively confined to their constitution and equilibrium diagrams. Except in connection with the manganese-copper-nickel alloys, there is little reference to mechanical properties and no specific mention of temper-hardening which is an important factor in the heat treatment of some alloys containing manganese. The possibility of such treatment of the manganese-aluminium-copper alloys is indicated only by the statement that the copper-rich "$\alpha$-phase field contracts as the temperature is lowered." It may be, however, that many manganese alloys of engineering importance (rather than those primarily of physical interest) are excluded from consideration as containing too small a percentage of manganese. The thermal, electrical and magnetic properties of alloys containing large percentages of manganese are fully recorded.

The book well maintains the high standard set by the earlier volumes of the series, and is to be welcomed as an authoritative account of the production of manganese in its various forms and degrees of purity, and of the properties of the pure metal and of the increasingly important alloys of high manganese content.

*Gas Turbine Series. Volume 2: Some Fundamentals of Combustion.* By D. B. SPALDING. London: Butterworth's Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 40s.

THIS book is one of a series which together are intended to cover the whole field of gas turbine theory and practice. The fact that two whole books out of a total of eight should have been devoted to combustion indicates the importance which attaches to this subject in the gas turbine field. As those concerned are only too well aware, the design of combustion chambers is still to a great extent a matter of trial and error, and a book which attempts to correlate theory with practice can be certain of being widely read and studied.

The author is well known for his work on the combustion of liquid fuels and, as he explains in the preface, the book is made up largely of those elements of thermodynamics, aerodynamics, heat and mass transfer and chemistry which he found it necessary to master as a preliminary to his work on combustion. Most of the subject-matter is concerned with fundamental theory, but the final chapter discusses the practical implications of what has gone before. The main value of this book is that it collects together a great deal of information which has previously been obtainable only from very varied sources, and there is no doubt that the practical engineer, for whom it is mainly intended, will find it of considerable assistance. The author also possesses a happy facility for clear and concise explanation, which is of particular value in a book which will be widely read by non-experts.

The most serious omission is the lack of any mention of the particular difficulties associated with the use of residual fuels, and this is all the more surprising in view of the well-recognised importance of this subject for most types of non-aircraft gas turbine. It may be that such matters as the atomisation of heavy fuels and the fouling and corrosion of turbine blades by ash have been held to fall within the scope of "combustion practice"; it may be hoped that these and kindred subjects will be fully dealt with in the forthcoming volume under this title.

### Books Received

*Ultrasonic Engineering.* By A. E. Crawford. London: Butterworths Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 45s.

*The Year's 16mm Films, 1954.* Published by Current Affairs, Ltd., Film User Office, 174, Brompton Road, London, S.W.3. Price 6s. 6d.

*Transistors and Other Crystal Valves.* By T. R. Scott. London: Macdonald and Evans, Ltd., 8, John Street, Bedford Row, W.C.1. Price 45s.

*Elementary Surveying.* Third Edition. By W. H. Rayner and M. O. Schmidt. London: Macmillan and Co., Ltd., St Martin's Street, W.C.2. Price 38s.

*Thermodynamics.* By J. F. Lee and F. W. Sears. U.S.A.: Addison-Wesley Publishing Co., Inc., Cambridge, 42, Massachusetts. Price 7 dollars 50.

# North of Scotland Hydro-Electric Schemes

## No. VI—THE TUMMEL-GARRY SCHEME*—PART I

*The North of Scotland Hydro-Electric Board's Tummel-Garry scheme in Perthshire will generate about 300 million kWh every year from three power stations. The second stage of the scheme—Errochty dam and power station—is now approaching completion and will be described in some detail in this article in Parts II and III. The first stage works at Clunie and Pitlochry are briefly explained herewith, as are the former Grampian Electricity Supply Company's works. Details of the electrical layout and operation at Clunie and Pitlochry stations are also given.*

THE Clunie and Pitlochry power stations of the Tummel-Garry scheme in Perthshire are now well-known achievements of the North of Scotland Hydro-Electric Board, for they have been completed and in operation since 1950. In fact, together with the Loch Sloy scheme they formed the first major developments which the Board promoted. The scheme at Loch Sloy was situated in an area which was virtually uninhabited, but the Tummel-Garry scheme involved changes in a more populous area, with the Pitlochry reservoir and power station on the fringe of a prosperous holiday town. The reaction of Scottish opinion to the first stage of the scheme was therefore a rather critical test for the Board, and the scheme received a correspondingly large share of publicity. Needless to say, the Pitlochry power station and Loch Faskally, its reservoir, are now considered to be definite attractions for holiday makers and sightseers at Pitlochry. The measure of the Board's success in achieving this situation will be evident from the brief description of the scheme which is included in this article.

The second stage of the scheme—the Errochty section—is now approaching completion, and so we have linked a more detailed description of it with the general account of the first stage and of the earlier hydro-electric works in the same catchment. Although some work remains to be done at Errochty dam, impounding up to an intermediate level (1035 A.O.D.) has been commenced. Errochty power station has been completed and the machines are now ready for turning round.

Parliamentary powers for hydro-electric development in the Tummel Valley were first obtained in 1922 (see THE ENGINEER, May 26, 1922), and subsequently the Rannoch and Tummel power stations were constructed by the Grampian Electricity Supply Company. These power stations were, of course, taken over by the North of Scotland Hydro-Electric Board when it was formed. Fig. 1 illustrates the development of the Tummel and Garry as it has actually been carried out up to the present, and for comparison Fig. 2 shows the works for which Parliamentary approval was obtained in 1922. It will be noted that not all of the works for which approval was then obtained were actually built. The Bruar power stations and associated diversion works were the principal parts of the scheme which did not materialise. The Board's post-war proposals extended further down the catchment to Pitlochry, which is, effectively, the lowest economic site on the river. The only streams now left unexploited by the Tummel-Garry scheme are, in fact, the two left-bank tributaries of the Garry, the Tilt and Girnaig.

The earlier schemes were based upon the extensive storage available in Loch Ericht; a dam and diversion works were built at the outlet of this loch and Rannoch power station was brought into operation at the end of 1930. The construction of these works was described in THE ENGINEER of August 7 to September 4, 1931. Subsequently the natural catchment supplying Loch Ericht was substantially enlarged by the construction of the various aqueducts shown in Fig. 1. The second stage of the

* No. I: "An Introductory Survey," appeared July 14, 1950; No. II: "The Loch Sloy Project," July 21-August 4, 1950; No. III: "The Fannich Project," June 8–15, 1951; No. IV: "The Mullardoch-Fasnakyle-Affric Project," April 11–25, 1952; No. V: "Some Schemes for Local Supply," October 16–23, 1953.

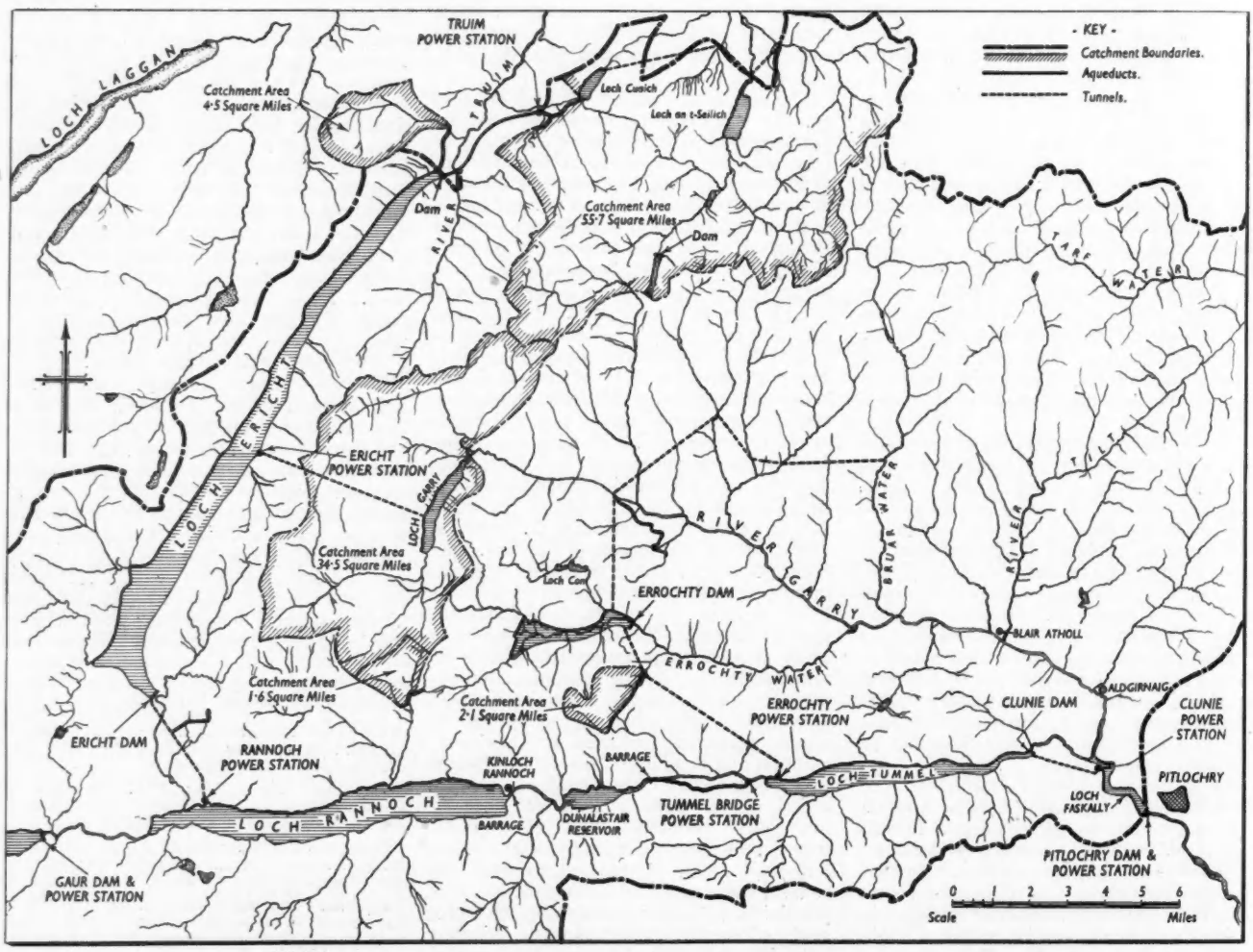



**Fig. 1—Catchments of the Tummel and Garry rivers showing the various hydro-electric developments in operation or under construction**

scheme, involving the construction of a regulating barrage across Loch Rannoch, a second barrage to form the Dunalastair reservoir, and the Tummel bridge power station and its associated diversion works was completed in 1933 (see THE ENGINEER, July 6–13, 1934). A very well-regulated supply was thus provided for the two stations by the Ericht and Rannoch reservoirs, and this fact influenced the design of the Tummel-Garry scheme, for a fully regulated supply could be relied on down the River Tummel.

The schemes now built have substantially developed the resources of the entire catchment, with the exception of the left bank tributaries of the Garry mentioned above. How this development has been achieved will be apparent from Fig. 1 and from Tables I and II, which give the principal data of the various reservoirs and power stations. The small Gaur scheme may be noted. This scheme was built by the Board and utilises a further 88 square miles of the catchment (the extent of which is shown in Fig. 2) not covered by the main schemes; it was described in THE ENGINEER of January 15, 1954, page 84.

All of these schemes have made provision for local amenities by providing compensation water and fish passes wherever necessary. The former Grampian Company's developments are not without detailed points of technical interest in their layout, and reference to our earlier articles makes an interesting comparison with present-day practice. In some cases the control of compensation water at the various intakes and weirs is carried out automatically and the Tummel bridge station has two rather unusual turbo-alternator sets. These sets comprise two Francis turbines and an alternator mounted on a common horizontal shaft. The turbines are next to each other, with a common governor gear, and they are supplied from a single penstock controlled by a butterfly valve situated in the machine room, with a bifurcation to each turbine inlet below the valve. This layout was adopted so that the turbines could be placed as high as possible above the possible flood levels of Loch Tummel, and model tests were carried out to find how high they could be positioned and yet still avoid cavitation troubles. These machines were described in THE ENGINEER of April 7, 1933; they are of almost the same power, and operate under about the same head as the vertical Francis machines at Clunie, and a comparison is again not without interest.

Within the last year or so, the North of Scotland Hydro-Electric Board has promoted two additional schemes, to complete the utilisation already substantially achieved by the Tummel-Garry scheme. Reference to Table I and Fig. 1 will explain the small additional power stations, one on Loch Ericht at the outfall of the Loch Garry–Loch Ericht tunnel, and one near the River Truim, which will make use of flows already diverted by existing works. It is also proposed to add certain small catchment areas to the scheme, as shown in Fig. 1, and to enlarge the Dunalastair aqueduct and raise its level, to get a better utilisation of the sets in Tummel bridge power station. Finally, the small Trinafour station will be built to utilise the compensation water which the Board is statutorily obliged to allow to flow down the Errochty water. Trinafour power station will be supplied by a pipeline from Errochty dam.

TABLE I—*Power Stations in the Tummel and Garry Catchment*

| Machines installed | Total installed capacity, MW | Mean annual output, kWh × $10^6$ | Load factor, per cent | Gross head, ft |
|---|---|---|---|---|
| **Built by the former Grampian Electricity Supply Co.:** | | | | |
| Rannoch: | | | | |
| Three vertical shaft Francis sets ... ... ... | 48 | 171 | 40·7 | 512 |
| Tummel bridge: | | | | |
| Two horizontal shaft, double Francis sets ... | 34 | 113 | 38·0 | 173 |
| Totals for Grampian scheme ... ... ... ... | 82 | 284 | 39·6 | — |
| **Built by the North of Scotland Hydro-Electric Board:** | | | | |
| Clunie: | | | | |
| Three vertical shaft Francis sets ... ... ... | 61·2 | 143 | 26·8 | 173 |
| Pitlochry: | | | | |
| Two vertical shaft Kaplan sets ... ... ... | 15 | 54 | 41·0 | 50 |
| Errochty: | | | | |
| Three vertical shaft Francis sets ... ... ... | 75 | 103 | 15·7 | 610 |
| Totals for Tummel-Garry scheme ... ... ... | 151·2 | 300 | 22·6 | — |
| Gaur scheme: | | | | |
| One vertical shaft Francis set; auxiliary 0·4MW horizontal Francis set | 6·4 | 17 | 30·4 | 92 |
| Tummel-Garry additions and amendments: | | | | |
| Ericht ... ... ... ... ... ... ... ... ... | 1·5 | 9 | 68·5 | 180 |
| Truim ... ... ... ... ... ... ... ... ... | 2·4 | 9·3 | 44·3 | 87 |
| Additional stream diversions ... ... ... ... | — | 10 | — | — |
| Enlargement of Dunalastair aqueduct ... ... | — | 4·4 | — | — |
| Trinafour ... ... ... ... ... ... ... ... | 0·6 | 1·8 | 41 | — |
| Total additional output ... ... ... ... ... | 4·5 | 34·5 | — | — |
| Totals for Tummel and Garry catchments .. ... | 242·9 | 628·5 | — | — |

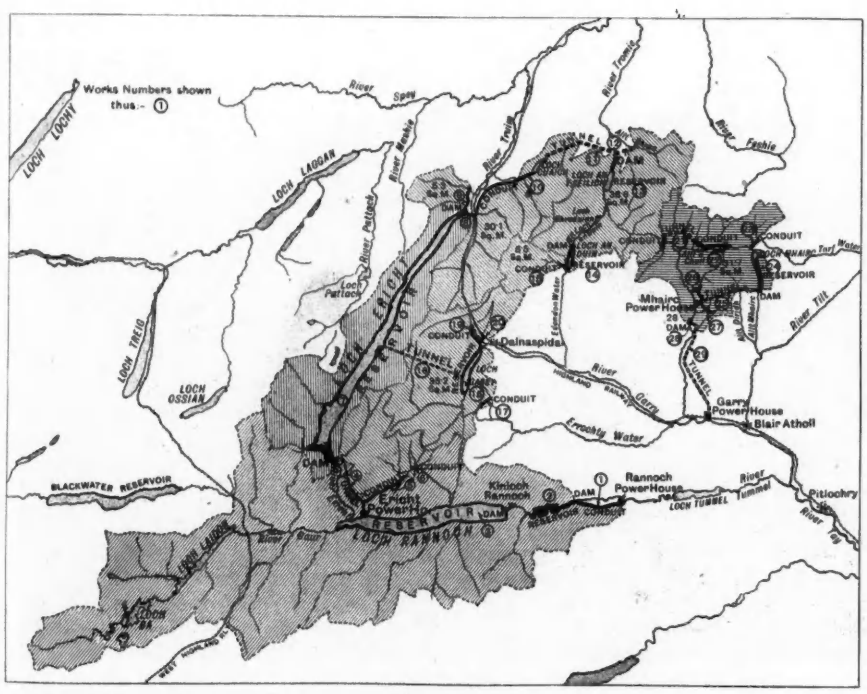



**Fig. 2—Original proposals for the Grampian hydro-electric scheme as authorised by the 1922 Act. Comparison with Fig. 1 indicates which works have actually been constructed**

## THE CLUNIE AND PITLOCHRY DEVELOPMENT

The first stage of the Tummel–Garry scheme formed a logical extension to the Grampian Company's works. Loch Tummel was enlarged by the construction of the Clunie dam (Fig. 3) and intake works and a tunnel were constructed to divert the water to Clunie power station (Fig. 4). This station operates on a rather low load factor, and the flow discharged from it, together with the unregulated flow from the River Garry (which joins the Tummel just upstream) is evened out by the operation of the Pitlochry station. The latter station is combined with the Pitlochry dam and forms a small narrow reservoir known as Loch Faskally, into the upper end of which the Clunie station discharges. Loch Faskally acts as a daily reservoir, with a draw down in level of about 5ft. Loch Tummel, although a very large loch, is not used to provide much storage for the normal operation of the scheme, because the draw down is normally limited to about 5ft; but in exceptional circumstances this figure can be increased to 15ft. One of the stipulations of the scheme, made in the parliamentary stage, was that the level of Loch Tummel should be kept within fairly close limits, so as to avoid unsightly foreshores along the picturesque valley in which the loch is situated. With the regulation provided further upstream this requirement was not too onerous, and so the function of Clunie dam is to provide a balancing reservoir for Clunie power station, raising the natural

TABLE II—*Reservoirs in the Tummel and Garry Catchments*

| Reservoir | Useful storage capacity, cubic feet by $10^9$ | Top water level, ft A.O.D. | Available draw down, ft | Details of dam forming reservoir | Maximum height of dam, ft | Length of dam, ft | Catchment area supplying reservoir, square miles |
|---|---|---|---|---|---|---|---|
| Built by the former Grampian Electricity Supply Company : | | | | | | | |
| Loch Garry ... ... ... | 420 | 1,360 | 30 | None | — | — | — |
| Loch Ericht ... ... ... | 6,912 | 1,179 | 31 | Concrete gravity dam | 45 | 1,402 | 178 |
| Loch Rannoch ... ... | 1,630 | 672 | 8 | Control weir, three 47ft span sluice gates and spillway section and earth embankment, fish pass | 11 | 675 | 379 (total) |
| Dunalastair reservoir ... | 41 | 650 | 3 | Control weir, two 25ft span sluice gates, spillway, including siphons and fish pass | 30 | 250 | |
| Total storage of Grampian scheme | 9,003 | — | — | | — | — | — |
| Built by the North of Scotland Hydro-Electric Board : | | | | | | | |
| Loch Tummel ... ... | 700 | 473 | 10 | Concrete gravity dam with drum-gates spillway. Two gates each 60ft by 16ft, and fish ladder | 70 | 380 | 520 |
| Loch Faskally (Pitlochry) | 70 | 300 | — | Concrete gravity dam with drum-gate spillway. Two gates each 90ft by 16ft, and fish ladder | 54 | 475 | 710 |
| Errochty ... ... ... | 1,040 | 1,080 | 50 | Concrete diamond head buttress dam | 130 | 1,300 | 90 |
| Total storage for Tummel Garry scheme | 2,030 | — | — | — | — | — | — |
| Gaur ... ... ... ... | 271 | 850 | 20 | Concrete gravity dam with fish ladder | 40 | 360 | 62 (direct) 88 (total) |

NOTE.—Rainfall varies throughout the catchment from 50in to 120in.

level of the loch by 17ft and giving daily regulation of flow.

## CLUNIE POWER STATION AND DIVERSION WORKS

Clunie power station operates under a head of only 155ft so that with a total output of 61·2MW large flows of water have to be catered for and the diversion works and turbines are of large size. The tunnel intake is close to the right abutment of Clunie dam and consists of an opening 114ft wide and 36ft high with coarse screens, behind which is a six-bay opening, 96ft by 45ft high, housing smolt screens. The latter screens have mesh openings 1in wide and ½in high, and a set of four screens, each 16ft by 11ft 3in high, is used to close each of the six bays of the opening ; one spare set of smolt screens is kept as a standby. These smolt screens are solidly built, and so far have given little trouble in maintenance. The smolt season generally finishes a few days before seasonal floods are expected and by judicious operation it is possible to take out the screens just before the floods arrive, thus obviating inconvenience due to fouling by flood debris. The smolt screens governed the size of the intake opening, and behind them the water passage reduces gently to a rectangle 19ft by 25ft 3in in size, which accommodates a bulkhead gate and a control gate, followed by a short transition to the standard horseshoe cross section of the tunnel.

The fish ladder at Clunie dam, and also at Pitlochry, is a " pool and orifice " pass ; the fish travel up the pass through circular openings which have been constructed at the centre of each of the cross walls forming the " ladder " of pools. These openings are equivalent to about 2ft in diameter, and are inclined, joining the invert levels of adjacent pools. The orifice fish pass was evolved specifically for the Tummel–Garry scheme and is considered to give better results than the older passes where the fish jump over each successive weir of the ladder. The pools of the orifice pass each increase in the water level by 1ft 6in ; resting pools are provided for the ascending fish.

The Clunie tunnel is 9200ft long and for 8700ft of its length has a horseshoe cross section, with an equivalent diameter of about 22ft 6in. It is the largest tunnel which the Board has built. The construction of the Clunie tunnel was described in THE ENGINEER of March 10 and 17, 1950, together with a description of the high-pressure tunnel of the Affric scheme. These two tunnels formed the subjects of papers at the Institution of Civil Engineers and abstracts from the papers and discussion were printed in this journal. At about that time, the " Swedish " drilling equipment and pneumatic concrete placers were coming into use in this country and their merits were discussed in our earlier articles.

The Clunie tunnel passes under the surge shaft without any abrupt change in level, but its cross section changes first to a 21ft diameter concrete-lined tunnel and then to a 21ft 6in steel-lined circular tunnel. At a point about 500ft downstream from the surge chamber there is a steel trifurcation followed by three 12ft 3in diameter buried steel pipe-lines, which slope down to the power station over a distance of about 250ft. The surge shaft is 110ft in diameter and nearly 100ft in height ; it is joined to the tunnel, which passes underneath the centre of it, by six 10ft by 6ft rectanguar openings. There are no control valves at this stage, control of flow being effected at the tunnel intake and the power station.

Clunie power station has been designed with careful attention to " amenity." The machine room is brightly decorated (it is illustrated in Fig. 5) and is overlooked by the control room balcony. Administrative offices are laid out on the control room side of the building. The two sets at Pitlochry are controlled from here, as well as the three sets of Clunie power station itself, and the power from both stations is transmitted to the switching station close to the Errochty power station, which forms a major connection in the Highland grid. The transformers and transmission lines have been placed in as inconspicuous a position as possible and only one overhead tower can be seen from the locality of the power station. At the entrance of the power station access road, an arch has

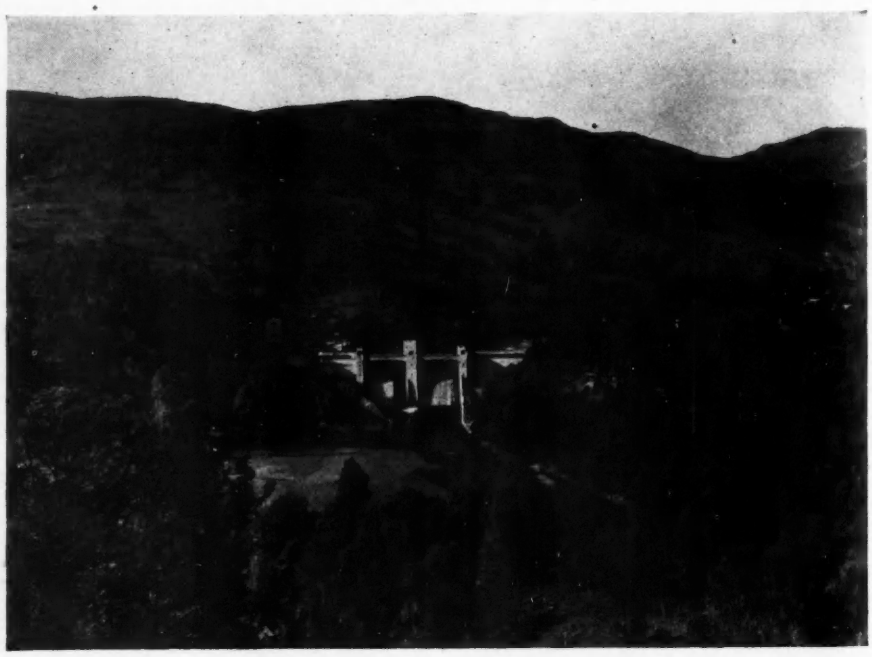


**Fig. 3—Clunie dam. The gate tower at the entrance of Clunie tunnel may be seen to the left of the dam. Between this tower and the top end of the fish pass are the coarse and fine screens. A small turbo-alternator utilising compensation water is installed in the building at the toe of the dam**

Fig. 4—Clunie power station. Water is delivered to the machines through buried steel pipelines, and the tail-race discharges into Loch Faskally. The transmission tower on the right takes power from the Clunie and Pitlochry stations to the switching station at Dalcroy

been built to commemorate the driving of Clunie tunnel. It is formed from the tunnel shutter itself, the idea being to give visitors an impression of the size of the Board's largest tunnel.

### Clunie Power Station Plant

The Clunie station has been designed for manual operation and equipped on a generous basis with a spacious control room and administrative offices. The generating units consist of three 20·4MW, M.C.R., 214 r.p.m., vertical Francis turbo-alternators generating at 11kV, 0·9 power factor. The net head varies from 165ft to 145ft and the turbines are designed to give their maximum efficiency at an output of 16MW and 155ft head. They are of standard design with welded plate steel spiral casings and cast steel guide vanes and runners with stainless steel protection on the wearing surfaces of the blades. The runner diameter is 9ft 3in ; the runners are single-piece steel castings weighing about 12 tons each. The turbine runaway speed is 400 r.p.m. The inlet valves are hydraulically operated butterfly valves, 11ft diameter. The alternators, rated at 22,667kVA continuous maximum, have the "umbrella" layout with single thrust and guide bearing mounted below the rotor. They have closed circuit cooling with provision for diverting a portion of the air from each alternator for heating the turbine room. Make-up air is obtained through filters and hand-operated louvres in the alternator plinths. Cooling water for the air coolers is taken from the spiral casings. The sets have a stator bore of 17ft 7in.

The power station auxiliaries are divided into four groups for the purpose of supply and control, namely, (*a*) those which are an integral part of each machine and are referred to as the "essential auxiliaries," comprising the main governor and bearing oil pumps. They are supplied via 415V unit auxiliary boards from 50kVA unit transformers. (*b*) Those which are common to the station as a whole and are supplied from a common services 415V board which can be energised either from the earthing transformers on the main step-up transformers or from the ring main from Tummel bridge to Pitlochry town, which is independent of the power station ; this board also provides a feed to each unit auxiliary board in order that a maintenance or testing supply may be given to the main governor and bearing oil pumps when the turbo-alternator set is idle. (*c*) A standby governor oil pump driven by an 18 h.p. Pelton turbine (and thus independent of any electricity supply other than the battery for control), which delivers into a bus pipe connecting the three main governor oil pumps. (*d*) D.C. standby bearing oil pumps (one for each machine), driven from the 240V supply from the main battery. The bearing oil system is common both to alternator and turbine.

The turbo-alternators are started on the standby pumps ; the first of these to be operated are the d.c. standby bearing oil pumps controlled by push button from the turbine panel. Following these the standby Pelton-driven governor oil pump, also under push-button control, is run up† and when governor oil pressure has been obtained the turbo-alternators can be started. The motor starters of the "essential auxiliaries" are of the latch-in type, normally left closed, with the result that as a turbo-alternator runs up to speed and voltage builds up on the generator and associated unit transformer, the main governor and bearing oil pumps take over automatically from the standby pumps. The Pelton-driven pump is cut out by push-button control from the turbine panels and is restarted automatically in the event of failure of a main governor oil pump resulting in the pressure in the oil bus pipe falling below a certain limit. After short periods of shut-down, however, sufficient pressure will remain in the governor air vessels to restart without using the standby pump.

When a turbo-alternator is shut down the fall of pressure from its main bearing oil pump, due to loss of volts on the unit transformer, will cause the corresponding standby d.c. pump to cut in. This ensures adequate lubrication while the set runs down to a standstill. The control circuits of the d.c. pumps are interlocked with the guide vanes of the respective turbine so as to ensure that the sets cannot be started without bearing oil pressure. This system, whereby the standby governor and bearing oil pumps are normally used for the operation of starting a set and not merely as emergency equipments, has the advantage that their availability is regularly proved.

Compressed air for the governor air/oil storage vessels is provided by a common motor-driven air compressor, and a separate Pelton-turbine-driven compressor facilitates starting the station without external power in the event of total shut-down.

All items of equipment which the turbine driver needs for manual control of the turbines are accommodated on the turbine panels at generator floor level, viz. machine controls, gauges and alarm indicators ; also at this floor level are the field control pillars, inlet valve emergency control pedestals, unit auxiliary boards and the governor actuators. The only equipment on the downstream side at main floor level consists of the hot air discharge "chests," and three pedestal flow meters which indicate, integrate and record the water used by each turbine. All the remaining machine auxiliaries are on the lower floors.

The main switchgear is single busbar, oil filled, metal clad, with 11kV, 750MVA rating. It is divided into two sections in separate compartments of the switch house which is an annexe of the turbine house, and provision is made for an outdoor bus section reactor rated at 5 per cent on 20,000kVA. The main feeder transformers consist of two banks of three single-phase units, each bank rated at 60MVA. They are situated on a concrete raft behind the switch house at the back of the station and immediately over two of the three pipelines. The water for the transformer cooling and fire protection is taken from the centre pipeline through pressure-reducing valves and is discharged to the tail-race. On-load tap-changing equipment has not been provided, but provision has been made for its inclusion later if required.

Fig. 5.—Interior of Clunie power station showing the exciters of the three 20MW turbo-alternator sets

The control room contains, in addition to the usual instrument and mimic diagram panels, a control desk, relay and voltage regulator panels and a panel for hydraulic

† The Pelton-driven stand-by oil pump maintains governor oil pressure during shut-down.

**Fig. 6—The fish pass and tail-race of the Pitlochry dam and power station. The precast concrete facing slabs used at both Clunie and Pitlochry power stations are shown to advantage on the corner of the power station**

indicating and recording instruments. On this latter panel are displayed and recorded measurements of reservoir levels and river flow below both Clunie and Pitlochry dams, and the duration of spilling conditions and compensation spates. Automatic release and indication of position of the intake gate at Clunie dam is also provided.

A central alarm panel is provided in the control room to give detailed display of operation of all the various fault, protective and warning devices on both mechanical and electrical plant, and also to give alarm of dam spill or intake gate release by the excess-of-flow device. Similar quantities are displayed on the same central alarm panel for Pitlochry dam and power station.

The output of the station is taken by a double circuit steel tower 132kV S.C.A. overhead line to Errochty substation. This substation is the collecting point for, and also the control centre of, the whole group of stations in this catchment.

Compensation flow at Clunie dam has to be delivered partly down the fish ladder, partly in spates, and the remainder by injection at the bottom of the fish ladder. This latter part of the compensation water consists of a constant discharge (46 cusecs) from May to November inclusive, and, with an available head of 46ft at the dam, is used to drive a 175kW turbo-alternator. The generator is an induction machine and the output is delivered to the 33kV line erected for giving constructional power supplies to the works from Tummel Bridge power station, and now to be used as a ring main via Clunie and Pitlochry power stations to Pitlochry town.

### Pitlochry Dam and Power Station

Pitlochry dam and power station is architecturally one of the Board's most successful ventures. It is illustrated in Figs. 6 and 7, which give a good idea of its general layout. The power station is faced with precast concrete blocks, which during construction were utilised to form the shuttering for the walls and which harmonise well with the mass concrete of the dam. The drum gates of the latter also give a clean appearance, free from overhead operating gear, which was one of the reasons why they were used. But their principal virtue is that they give a sensitive and effective spill control at all flood flows with virtually no change in reservoir levels. The discharge capacity of the gates (i.e. when they are completely lowered and with the water at 301ft O.D.) is about 44,000 cusecs. There are no transformers or power lines leaving the station, the power being transmitted at its generated voltage by underground cable to Clunie power station. The interior of the power station is of clean appearance, with only the exciters of the two alternators projecting above the main floor as at Clunie.

The first half of the dam and the power station were built inside a steel-sheet-piler cofferdam, the river being constricted to flow in the other half of its channel. At a later stage the other half of the river bed was sealed off by a second cofferdam, the river then flowing through temporary openings left in the first part of the dam. An extensive cut-off trench had to be built in the moraine on each side of the dam. On the Pitlochry side it extended for 900ft and to a maximum depth of 130ft. On the other side the cut-off wall was built in heading for 250ft. The construction of the scheme has been described in a paper by Bennett.‡

The extensive smolt screens used at Clunie were omitted at Pitlochry barrage; it was observed that smolts could pass through the Kaplan turbines at Pitlochry, where the head is only about 45ft, without injury, and so only trash screens were necessary.

The Board carried out various road works in the neighbourhood of Pitlochry dam and reservoir, and also built a new sports ground to replace one which had been submerged. The road works include a reinforced concrete bridge of three spans, the Aldour bridge (see THE ENGINEER, September 30, 1949), situated a short distance below the power station, with approach roads. A new footbridge was also built across the reservoir. This structure is of interest (see THE ENGINEER, October 13, 1950), as it was one of the first bridges to be built of aluminium.

### Pitlochry Power Station Plant

Pitlochry power station may be considered electrically as an extension of Clunie power station, though hydraulically and physically it is quite separate. It is manually controlled from within the station only for the operations of starting and stopping the machines. Synchronising and loading are carried out from the control room at Clunie, the output from the sets being transmitted at 11kV, the generation voltage, by 2½ miles of cable between the two stations. The generator switches for the Pitlochry sets are located at Clunie as part of the main switchboard. The Pitlochry station therefore has no control room nor main switch house and the layout is simple, though liberal office accommodation has been provided.

The generating sets consist of two 7·5MW vertical Kaplan turbo-alternators running at 167 r.p.m. under a mean net head of 46ft and generating at 11kV, 0·9 power factor. The turbine runner blades are of cast stainless steel; the runner has four blades and has a nominal diameter of 10ft 9in. The intakes and spiral casings are formed in concrete throughout, the intake for each machine being divided vertically into halves. No automatic intake gates or inlet valves are

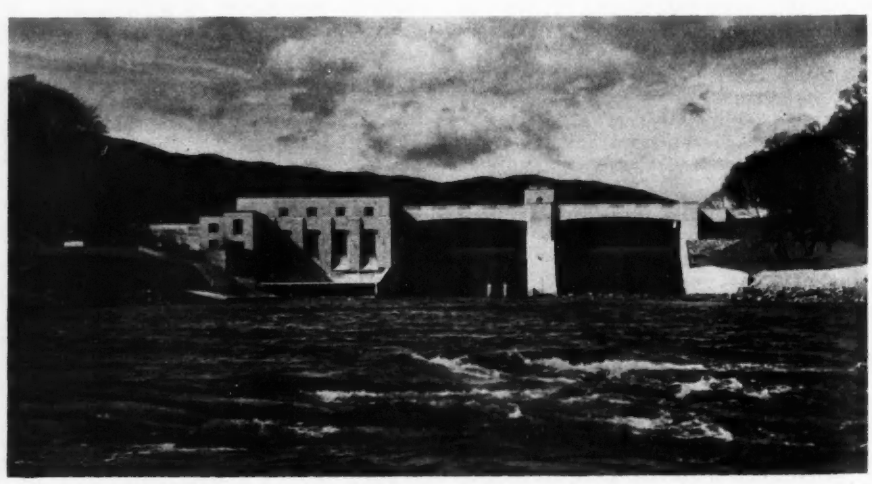


**Fig. 7—The dam and power station at Pitlochry seen from downstream. The drum gates each span 90ft and a flood of over 40,000 cusecs can be passed without increasing the reservoir level**

‡ "Pitlochry Dam and Power House and Clunie Dam," by J. A. Bennett. Symposium of four notes on contractor's site layout. *Institution of Civil Engineers*, 1949.

provided, but merely a pair of bulkhead gates, which can be lowered into the twin intake passages of either turbine so that the spiral casing can be drained to carry out maintenance on the turbine.

The auxiliaries at this station, while operating on the unit principle as at Clunie, with the "essential auxiliaries" supplied from unit transformers, differ in two respects. First, on account of the low head, a water-driven standby governor oil pump on which the turbo-alternators may be started up is not practicable ; and secondly, it is not possible to have d.c. standby oil pumps, since, there being no main switchgear, there is no requirement for a main station battery (the 240V d.c. control supply is brought over pilot wires from Clunie). Accordingly the auxiliaries are arranged as follows :—

(*a*) The "essential auxiliaries," i.e. the main governor oil pumps and the generator bearing oil pumps (this station has independent turbine and generator lubricating systems), are supplied via 415V unit auxiliary boards from 150kVA unit transformers.

(*b*) A small standby governor oil pump is geared to each turbine shaft, merely for slow closure of the guide vanes in the event of emergency shut down with consequent loss of a.c. supply from the unit transformers. These pumps are not sufficient for normal standby governor duty and the governor systems at this station are not interconnected.

(*c*) The main turbine bearing oil pumps are gear driven from the main shafts.

(*d*) All other auxiliaries including the standby generator and turbine bearing oil pumps, are supplied from a 415V common-services switchboard, which can be energised either from the ring main already mentioned or from either of the unit transformers, which are accordingly larger than those at Clunie.

The turbo-alternators are started in a similar manner to those at Clunie with the exception that the main governor oil pump motors are switched over to the common services switchboard until they can derive their supply from the unit transformers. It has been necessary in this design to accommodate rather more of the auxiliary equipment on the generator floor than at Clunie, where it is mostly on the lower floors. At this station the turbine and field control panels are along the upstream wall as at Clunie, but the governor oil pumping sets, with their oil tanks, the governor air compressor and brakes air compressor, are on the generator floor on the downstream side. All other machine auxiliaries are, however, on the turbine floor below.

A hydraulic panel is provided on which are mounted the two turbine flow meters and integrators, and a recorder for registering the quantity of water spilled over the drum gates. A river flow indicator is also provided.

As also at Clunie, a small water-turbine-driven induction generator is installed to use the compensation water which it is necessary to pass and which amounts to 18·5 cusecs continuously throughout the year. The available net head is 37ft and the capacity of the set 50kW, giving an annual output of 0·43 million kWh. This output is delivered both to the common services l.v. switchboard in the power station and to the ring main connecting Tummel bridge to the Pitlochry town network. The compensation water thus used is additional to the flow which is passed by the large fish ladder.

(*To be continued*)

# Exhibition of Peaceful Uses of Atomic Energy at Geneva

No. V—(*Concluded from page* 301, *August 26th*)

SPECIALISED instrumentation took a prominent place on many of the stands at the exhibitions held in conjunction with the recent Geneva conference on the peaceful uses of atomic energy. Some examples from the British exhibits are briefly described here.

Among the exhibits shown by the U.K. Atomic Energy Authority was a recorder for the routine plotting of cooling and heating curves of alloys in metallurgical research. In this instrument the temperature, the rate of cooling or heating, and the difference in temperature between the alloy and the furnace are plotted concurrently to give a full record of any particular experiment. During the exhibition the recorder was demonstrated plotting the heating and cooling curves for a lead-tin-bismuth alloy in a small furnace.

Each of the measurements is made in terms of thermocouple e.m.f's. For the first quantity, that is the temperature of the metallurgical specimen, the required accuracy is obtained from the thermocouple e.m.f. by dividing the total range of 25mV into 1mV spans by successive and automatic zero suppressions ; the magnitude of the zero suppression is also printed on the record. The second quantity recorded, that is the rate of change of temperature of the specimen, is derived by storing the value of the instantaneous temperature, comparing it with the value prevailing thirty seconds later and recording the difference on a span of ±50 microvolts. These two operations together with the third one (measurement of temperature difference between specimen and furnace) and with the automatic standardisation of the recorder constitute a cycle which occupies one minute.

Another instrument in the same group of exhibits was a diaphragm micromanometer designed for flow measurements with corrosive gases and for certain applications in mass spectrometry. It gives a rapid, direct and linear indication of differential or absolute pressure and has three ranges, of which the most sensitive is 0–50 microns Hg. In this instrument the gas pressure is applied across a thin metal diaphragm and the resulting deflection is detected by a change in the inductance of a sensing coil mounted in the cover of the pressure chamber. This sensing coil forms part of a "Bridge-T" circuit energised from a fixed-frequency oscillator and is tuned to give null reading when the differential pressure is zero.

The fact that light and heavy water can be distinguished by their different absorptions of infra-red light forms the basis of a spectrometer exhibited by the U.K. Atomic Energy Authority as a means of measuring the concentration of heavy water in a mixture of light and heavy water. This spectrometer which is a recent development makes use of a Merton-N.P.L. diffraction grating, F-centre crystals and a photo-conductive detector for determination of heavy water concentration.

A sonic analyser designed for the continuous routine analysis of binary mixtures of light and heavy gases was also on show ; it was demonstrated working with mixtures of air and carbon tetrachloride vapour. This analyser depends for its operation on the fact that, at a given temperature the velocity of sound through binary mixtures of gases is a direct function of the velocity of sound through the constituent gases and of their relative concentrations. To make this analysis the gas sample is passed through a resonator of "double Helmholtz" form and the sonic velocity is deduced from the frequency of the gas resonance which is excited and detected by electromagnetic transducers set in the resonator walls, in conjunction with a variable-frequency oscillator and amplifier detector. A typical value of the resolution (or "Q" factor) of the resonator is 45 and it is stated that the sonic velocity can be determined within ±0·2 per cent.

The U.K. Atomic Energy Authority's display also included ionisation chambers, which have been specially designed for reactor instrumentation. One of the requirements for this class of duty is that the chamber should contain, in a minimum volume, the maximum quantity of fissile material in the form of an oxide film of thickness up to 1 milligramme per square centimetre. This condition has been satisfied by depositing the active material upon a set of closely-spaced, interleaved, coaxial nickel cylinders which constitute the electrodes of the ionisation chamber. Natural uranium, uranium enriched or depleted in U235, and Pu239 are among the fissile materials that have been used so far and pure argon at pressures up to 10 atmospheres has been the gas filling. Normally the chambers are operated at a potential difference of 300V to 500V and with time constants sufficiently short to allow electrons only to be collected.

### British Instrument Makers' Exhibition

A prototype of a micro-microammeter designed for the measurement of ionisation current and intended for industrial use was one of the new instruments shown by Elliott Brothers (London), Ltd., Century Works, Lewisham, London, S.E.5. This company has developed the micro-microammeter in conjunction with the U.K. Atomic Energy Authority. It embodies a sub-miniature electrometer triode and two magnetic amplifier stages. Direct feedback via switched high-value resistors enables linear current measurement to be achieved in six ranges having full-scale values from $10^{-11}$A to $10^{-6}$A. The output is suitable for the direct operation of pen recorders, and the total power consumption of the unit is 20W.

To ensure maximum stability the electrometer valve and high-value resistors are housed in a sealed and desiccated unit. This unit is detachable and may be conveniently operated remotely from the instrument, thus easing the problem of siting with relation to ionisation chambers. An internal stabilised supply is provided for ion chamber polarisation. A magnetic amplifier unit, providing warning when the input current exceeds a preset level, can be incorporated, if required.

The same company is developing a recording beta and gamma monitor on behalf of the Atomic Energy Research Establishment. Continuous monitoring of radiation levels in the vicinity of nuclear plant can be carried out with this recording instrument. It is designed for reliable outdoor service and makes use of two halogen-quenched Geiger-Müller counter tubes, which are mounted in close proximity under a light alloy cowling to provide protection against rain. One tube is screened from beta activity but detects gamma activity from all directions, the weather shield offering virtually no screening to this. The second tube responds to beta

activity in addition, although, because in this case the weather shield provides effective screening, it covers ground radiation only.

There are separate five-figure drum counters to indicate the total counts due to gamma only and gamma plus ground beta. For the latter the count rate also is recorded continuously on a seven-day circular chart, scaled logarithmically from 3 to 300 counts per second and employing "Teledeltos" electrosensitive paper. An auxiliary marking on the periphery of the chart indicates the total count, giving a permanent record in addition to the drum counter indication.

The instrument as exhibited consists of a light alloy casting in which the recorder and electrical circuits are mounted. An extension arm carries the Geiger-Müller tubes clear of the main unit. A cold-cathode ratemeter is used with a linear magnetic amplifier to provide sufficient current to operate the recorder. The range of count-rate extends from that corresponding to natural background to two decades above this.

Two forms of flowmeter that are being developed by the company are of interest. The first offers the attractive prospect of enabling the rate of flow in liquids to be measured electromagnetically. It is designed for low rates of flow in a wide variety of radioactive corrosive liquids. It is characterised by clean internal flow boundaries and by the absence of moving parts so that clogging by suspended particles is minimised and the pressure drop is reduced. The Elliott electromagnetic flowmeter "ND31" as exhibited consists briefly of a flow-measuring assembly and a high-gain amplifier which may be installed some distance away; it is suitable for rates of 0 to 100 c.c. per minute, but other ranges can be provided. The accuracy of indication is stated to be ±1 per cent of full scale, with a high degree of linearity over the whole operating range.

The second kind of flowmeter is one which is being developed primarily for the display of transient and oscillatory waveforms. Under certain conditions it can be used for measuring steady flow; in its present form it is suitable only for short-term recording or for work with fluids having constant characteristics, but progress is being made towards the removal of such limitations. The fluid under study is passed through a detecting element pick-off which, in the present prototypes, is capacitance-actuated. The output from this unit is available either on a meter (showing static or r.m.s. value of the flow) as a modulated 1500 c/s carrier, or demodulated. Demodulation involves a slight lag but this lag can be reduced to less than 2 milliseconds if required.

In its present form the instrument is unidirectional and shows only one-half of an alternating waveform. The instrument also suffers from temperature sensitivity and unsuitability for conducting fluids. The manufacturer is now developing prototypes which will be free from the first two limitations. Later, by making use of inductive pick-offs, it is planned to make the instrument suitable for all fluids.

A radiation monitor (Fig. 20) which has been developed by Ericsson Telephones, Ltd., Beeston, Nottingham, in collaboration with the Atomic Energy Research Establishment, Harwell, was demonstrated as a means of tracing a radioactive source. A source of gamma radiation was hidden in a dummy wall and the monitor was then demonstrated under conditions simulating those that would be met when tracing the source of radioactive contamination in a laboratory or building.

The equipment consists of a monitor unit, an alpha probe and a beta-gamma probe. The monitor unit is a self-contained battery-operated instrument housed in a mild steel container. It is designed to operate in conjunction with either of the above-mentioned probes. It is an integrated-count ratemeter and the full-scale deflection of its indicating element corresponds to 10, 100 or 1000 counts per second, according to the setting of the count-rate selector switch. Two Mallory "R.M.12" mercury cells supply the heaters and the power supplies for h.t. and e.h.t. are derived through a vibrator power pack, from four more "R.M.12" mercury cells. The h.t. supply is stabilised by a neon tube which is also used as an "On-Off" indicator. The monitor itself weighs about 10 lb and measures 11½in by 10in by 3½in. The alpha probe uses the scintillation principle for the detection of radioactivity and embodies an eleven-stage photo-multiplier tube with a zinc-sulphide-on-"Perspex" phosphor. This probe has a barrel diameter of 3½in and a height of 8½in and the overall window dimensions are 4½in by 4½in.

Fig. 20—Radiation monitor suitable for tracing a radioactive source, such as radioactive contamination on the walls or floor of a building

Another exhibit (Fig. 21) is the portable field ratemeter, type "1368," developed jointly by Ericsson Telephones, Ltd., and the Atomic Energy Research Establishment, Harwell, to facilitate prospecting for uranium or thorium, geological mapping and the examination of mine workings. It has facilities for assaying samples of radioactive ore in the field, independently of a laboratory. The equipment is fully "tropicalised" to Inter-Service Test Specification K114F, and consists of two main items—a ratemeter and a probe.

The ratemeter (on the right of Fig. 21) houses batteries, rate-meter circuits, indicating meter and gamma-ray sensitive Geiger-Müller tubes, including a low intensity tube for use where the background count is high. Transistors are used wherever possible in the circuits. The instrument case is of "Permali," hermetically sealed and fitted with a desiccator to absorb any moisture present in the main compartment prior to sealing. A separately-sealed compartment houses the batteries without a desiccator, since moist conditions are required for optimum battery performance and long shelf-life. The shock-mounted indicating meter is next to the handle, where it can easily be seen when the instrument is being carried. All the controls are mounted on a recessed panel to give protection against accidental damage. Visual indication is given on a 50 micro-ampere meter, and there is a socket into which headphones can be plugged to give audible indication.

The probe (on the left of Fig. 21) is used to adapt the ratemeter for the estimation of beta-active ores and for the examination of radioactive veins. It consists of a beta-sensitive Geiger-Müller tube and the associated amplifier in a hermetically sealed cast-aluminium case. The Geiger-Müller tube projects through the top of the case and is protected by a skeleton metal frame. A radiation cylinder fits over the skeleton frame and has a 90 deg. window on one side to expose the full sensitive length of the tube. An adjustable shutter on the radiation cylinder allows the window opening to be adjusted to any angle between 0 deg. and 90 deg. There are four ranges on the beta probe giving from 30,000 to 750 counts per minute at full scale deflection.

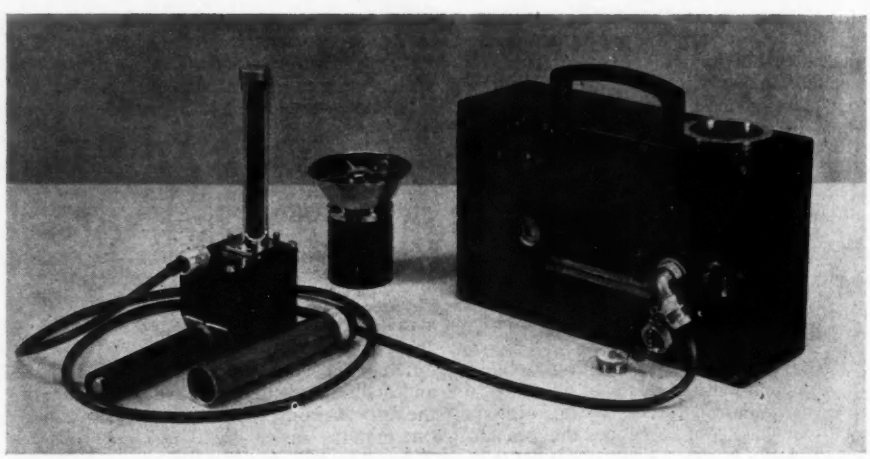


Fig. 21—Portable field ratemeter and probe suitable for uranium- or thorium-prospecting, for geological surveys or for field assaying of radioactive ores

Two applications of the field ratemeter were demonstrated at the Geneva exhibition: first, tracing the course of radioactive veins in a rock face; and, secondly, the assaying of radioactive ore in the field.

New instruments shown at Geneva by Labgear (Cambridge), Ltd., Willow Place, Cambridge, included a triple-gate ratio-counter (Fig. 22). It is a five-decade counter-control unit which is designed for use in conjunction with two auxiliary counters, to obtain a direct reading of the count ratio

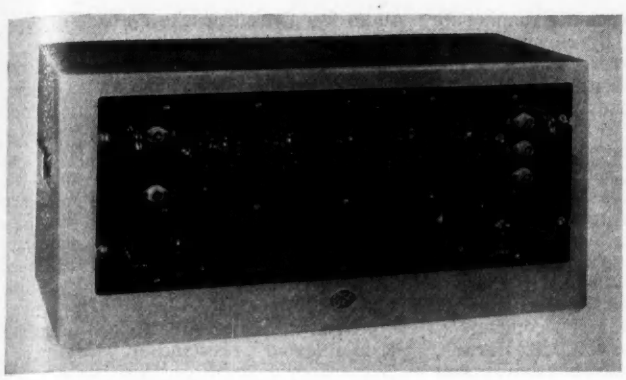


Fig. 22—Triple-gate ratio counter for use in conjunction with two auxiliary counters to give direct reading of ratio between three pulse sources

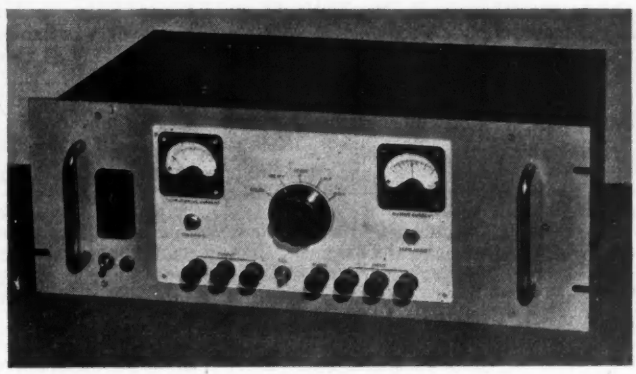


Fig. 23—Direct-current amplifier for thermocouple and strain gauge measurements

existing between three pulse sources, after the registration of a suitable unit-count in any chosen channel. Typical examples of techniques such as this are found in X-ray analysis, and uptake measurements with iodine 131.

The counter itself consists of five glow-transfer decade tubes with hard-valve input and interstage-couplings giving a capacity of 100,000 counts. There are three hard-valve electronic gates for the control of the pulses derived from three separate sources: one gate feeds the counter mentioned above; the other two gates feed two modified D.4104/B counters which are normally used with this instrument for ratio counting. The three gates are connected in parallel and are opened by the depression of the count key. The count is ended either by returning the count key to the stop position or from a voltage step (coinciding with the registration of a unit number of counts) selected from any one of the three channels by the auto-stop control; internal auto-stop pulses are available at $10^2$, $10^3$, $10^4$ and $10^5$ counts at 30V peak amplitude. A zero-reset position on the count key enables the whole registered count to be cancelled when required and the modified auxiliary counters can be linked for a common reset control.

A stabilised power pack built into the equipment provides for satisfactory operation of the instrument, with mains supply fluctuations up to 10 per cent. The whole instrument is arranged for standard G.P.O. rack mounting and is enclosed in a vertical cabinet measuring 7in by 19in by 8in, the total weight being 20 lb.

Multi-gun cathode-ray tubes and a variety of quenched-halogen Geiger-Müller tubes were among the exhibits shown by 20th Century Electronics, Ltd., King Henry's Drive, New Addington, Croydon, Surrey.

The Geiger-Müller tubes included one which can be used to trace the movement of radioactive isotopes in the human body and is so small that it can be introduced into a blood vessel. It has a wall thickness of less than 0·003in with a central electrode of about 0·0002in diameter. The outer tube is made of stainless steel. A cathode-ray tube, one of a range of tubes exhibited, having flat faces ground and polished internally and externally, is shown in Fig. 24. These tubes are accurately made, to be suitable for direct measurements. The example illustrated here has four guns (that is, four channels) and can be used for the simultaneous study and correlation of up to four related phenomena.

The same company also showed a miniature mass spectrometer, which has been made in collaboration with the U.K. Atomic Energy Authority and is intended for the detection of leaks in large vacuum apparatus.

A pulse-height analyser was shown by Sunvic Controls, Ltd., 10, Essex Street, Strand, London, W.C.2 (a member of the A.E.I. group of companies). This equipment is designed to receive electrical impulses from any source and classify a random selection of the pulses according to amplitude into sixty, eighty or 120 groups dependent upon the setting of the channel selection switch. If desired, all pulses below a given amplitude can be ignored by adjusting the bias level controls. Check facilities are provided and brought into use in one position of the input switch. This company also showed a d.c. amplifier (Fig. 23), which is designed for the accurate measurement and recording of small d.c. potential differences, as encountered in thermocouple and strain gauge work, where sensitivity, speed of response and stability are essential. In conjunction with a standard cell it is possible to provide a voltage source which is continuously standardised to one part in 10,000. The long-term stability is given as ±6 per cent and the speed of response as one-tenth second full scale. Ranges of 0–1mV, 1mV, 10mV, and 100mV are provided as a standard, but other ranges can be made available.

New apparatus for nuclear research shown by Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2, included a 99-channel pulse-amplitude analyser based on a design evolved by The Atomic Energy Research Establishment, Harwell. It consists of an amplifier, a gating and coincidence circuit, a memory and comparator circuit, and a sorting and indicator unit with a "resettable" mechanical register.

Fig. 24—Four-gun cathode-ray tube for simultaneous study of four phenomena

A pulse generator, designed for applications where a very accurate output pulse height is required, was also shown by this company. This generator is specially suitable for such duties as checking the performance of multi-channel pulse-amplitude analysers. Adjustments in steps of 1 per cent can be made in the pulse height from the generator. Equipment for measuring radioactive contamination of personnel included the Philips Hand and Foot Monitor, type 1027. The main function of this monitor is to check the hands and clothing for alpha and beta-gamma contamination and the feet for beta-gamma contamination. The external finish is smooth and all parts are easily removable for cleaning.

Laboratory instruments, industrial instruments and instrumentation for reactors were shown by Isotope Developments, Ltd., 120, Moorgate, London, E.C.2. The first-mentioned group of instruments included a ratemeter and probe unit suitable for use as a self-contained contamination monitor, and a battery-operated portable survey meter for measuring dose rates of beta, gamma and X-rays. Among the industrial instruments there were a package monitor for checking the filling of proprietary products into packages, and an ionisation anemometer for the measurement of very-low-speed air currents, from 10ft to 300ft per minute. A geological survey instrument was also shown, in prototype form, based on a scintillation counter (using a photo multiplier and crystal) with transistor-engineered circuits. Another exhibit on the same stand showed a reflection-type wall thickness gauge for determining the thickness of flat or curved surfaces such as sheet materials and pipes. It does not involve the use of a contact fluid or need any preparation of the metal surface, and it is designed specially for use in the field.

Equipment for sampling radioactive dust was shown by Fleming Radio (Development), Ltd., Stevenage, Herts. This dust sampling set is basically a household suction cleaner fitted with a special nose piece, which contains a filter paper holder and an anemometer. The dust from the air sampled is collected by filtration through the circular filter paper disc, of 5cm effective diameter. The total air passed through the filter paper in a given time is measured by the anemometer. Using good quality filter paper, which combines low air resistance with good filtering efficiency, the rate of air flow is about 150 litres per minute. An air bleed, between the filter paper and the motor, passes enough air to keep the motor reasonably cool even if the filter paper becomes clogged. A flexible attachment, 12ft 6in long, allows samples to be taken from, for example, the "work point" on a machine which is being used for fabricating radioactive material.

The motor is designed for 230V, 50 c/s, single-phase supply.

A mains-operated ratemeter "5054," designed for use with both scintillation and Geiger counters, was shown by Panax Equipment, Ltd., 173, London Road, Mitcham, Surrey. This instrument incorporates a stabilised e.h.t. supply, which is variable from 0V to 2000V, a discriminator, and a pre-amplifier for pulses of 0·1V to 50V.

The instruments shown by the Automatic Coil Winder and Electrical Equipment Company, Ltd., 92–96, Vauxhall Bridge Road, London, S.W.1, included the "Radiac" survey meter, which is a portable self-calibrating apparatus for measuring gamma and beta radiation with a maximum indication of 500 r per hour. Another exhibit was the "AVO" d.c. amplifier, type "1388A," which is designed primarily for the measurement of ionisation chamber currents.

An air-in-argon indicating outfit was one of the instruments shown by the Cambridge Instrument Company, Ltd., 13, Grosvenor Place, London, S.W.1. The equipment consists of a 10in indicator, with a range from 0 to 3 per cent air in argon, and a measuring panel with a quick-acting square-block Katharometer, a drier, a flow gauge and a control valve. This company also exhibited a direct-writing polarograph (with thermostat and "Univector" attachment) for the rapid analysis of solutions by the Hevrovsky dropping-mercury-electrode method. The "Univector" attachment is an accessory which enables a pure a.c. voltage to be superimposed on the standard d.c. voltage applied to the Hevrovsky mercury dropping system. This arrangement produces polarograms that are more sensitive and simpler to resolve than ordinary step polarograms. Two forms of the Cambridge electronic recorder were also shown—a single-point recorder and a multi-point recorder for six points.

### Auxiliary Equipments

A selection of rotary and diffusion pumps and high-vacuum gauges was shown by Edwards High Vacuum, Ltd., Crawley, Sussex. The display included examples of the company's "Speedivac" vapour diffusion pumps, which are made in diameters ranging from 1in to 24in. Ultimate vacua of $10^{-6}$ (mercury) or $5\times10^{-6}$ (oil) are specified, and the speeds range from 10 to 12,000 litres per second. Besides the standard range special vapour diffusion pumps are made. For example, the 1in and 2in pumps can be cooled by forced draught instead of water, making them specially suitable for use in mobile pumping plants. The 2in mercury vapour pump "2M4" is designed for a backing pressure of up to 30mm of mercury, while producing an ultimate vacuum of $10^{-6}$mm of mercury. The oil vapour pump "F203" embodies special fractionating devices, whereby an ultimate value of $5\times10^{-7}$mm of mercury can, it is stated, be obtained.

"Speedivac" vapour booster pumps have recently been introduced by the company to meet a demand from industry for a pump free from the difficulties of gas and vapour evolution in the pressure range of $10^{-3}$ to 1·0mm of mercury. For it is in these pressure ranges that the normal vapour diffusion pump and rotary vacuum pump have low pumping speeds, leading to prolonged pumping cycles. "Speedivac" booster pumps are designed to reduce these pumping periods, for they have speeds of 40, 850 and 1300 litres per second and give an ultimate vacuum of better than $10^{-4}$mm of mercury.

A glandless pump suitable for atomic energy applications (where leakage of the liquid being pumped is undesirable, or where long periods of maintenance-free running are required) was exhibited by Hayward Tyler and Co., Ltd., Luton, Beds. Pumps of this design can be made to withstand pressures of several thousand pounds per square inch and for horsepowers up to 2000. For boiler circulation duties the pump and motor case are made of carbon or alloy steel, but for duties where contamination of the water must be kept to a minimum, for example, circulation through a reactor, the whole unit is made from corrosion-resisting material. This pump is generally similar to the one described and illustrated in our issue of June 3, 1955, page 774. The company is also co-operating with the A.E.R.E., Harwell, in the design and production of a similar unit for pumping liquid sodium.

A flat linear induction pump which has been developed for the pumping of liquid metals, by the Nelson research laboratories, was shown by the English Electric Company, Ltd., Marconi House, Strand, London, W.C.2. For demonstration purposes during the exhibition the induction pump was shown pumping mercury.

Various examples of pipework as supplied for the Calder Hall power station were shown by Aiton and Co., Ltd., Derby. They included a low-pressure steam crossover pipe having a 12in bore and fitted with loose Corwel flanges at both ends. A full-size working exhibit was shown to demonstrate the axial flexibility of two 22in bore bellows expansion joints. A section of 9in bore by 1⅛in thick austenitic steam pipe was exhibited to represent this company's technique in the manufacture of pipework for extra-high pressures and temperatures.

### Air Filtration

A variety of filters for use in radioactive areas were shown by Vokes, Ltd., Guildford, Surrey. In such areas particles of solid matter of sizes between 0·1 and 5 microns can cause trouble comparable with that produced by coarser matter in non-radioactive areas. To meet these requirements the company has developed special high-efficiency filters of various basic forms, in an effort to justify the claim of "absolute" air filtration.

The original "absolute" filter evolved in the United Kingdom by Vokes, Ltd., in conjunction with Government departments, was of the cylindrical canister form and employed either a resin-impregnated wool lap or an asbestos fibre wool lap, as its medium. Because of its comparatively low rating in terms of air flow capacity, search has since been made for a similar filter with larger flow capacity and providing means of total destruction after use in radioactive or toxic areas. Paper panel filters encased in wood have solved some of these requirements, but the range of filters now offered also includes prefilters of more conventional specification and other types as alternatives to meet various conditions of air supply, either intake or efflux.

The sub-micron high-efficiency air filters developed by the company include the new Vokes "55" Absolute paper filter which has a rated capacity of 1000 cubic feet per minute, a resistance of 1·1in w.g., and an efficiency of 99·95 per cent methylene blue; the paper element is easily disposable by incineration. Similarly the Vokes "44" Absolute paper filter has a rated capacity of 1000 cubic feet per minute, a resistance of 0·55in w.g., and an efficiency of 65 per cent methylene blue. For smaller rated capacities up to 200 cubic feet per minute the Vokes resin-wool and asbestos-wool canisters (the original deep-lap filter, as used by the U.K. Atomic Energy Authority) give efficiencies up to 99·999 per cent methylene blue.

The company also exhibited general-purpose air filters for intake air to laboratories and radioactive areas or for use as pre-filters for effluent air from radioactive areas. The exhibits included the "K600" air filter, with a rated capacity of 600 cubic feet per minute, a resistance of 0·15in w.g., and an efficiency of 99·9 per cent down to 5 micron particle size. The same efficiency is quoted for another filter that was exhibited—the "P" range "Microvee" dry fabric panel air filter which is made in five sizes, with rated capacities of 65 to 700 cubic feet per minute and a resistance of 0·25in w.g.

## Shipping at United Kingdom Ports

According to the *Board of Trade Journal*, the total net tonnage of shipping which entered the United Kingdom ports during the second quarter of this year was, at 19·7 million tons, 8 per cent more than the first quarter of the year and 7 per cent higher than the corresponding quarter in 1954. These figures, representing entrances with cargo in the foreign trade, were attained despite the dock strike and indicated the continuing high level of imports. Movement in the reverse direction, however, showed that cargo clearances totalling 11·8 million tons were slightly higher than the previous quarter, but 9 per cent less than the second quarter of last year. The influence of the dock strike was shown in the net tonnage of ships cleared in ballast, the total, at 11·8 million tons, being 13 per cent more than in the first quarter of the year and 19 per cent greater than for the second quarter of 1954; however, entrances in ballast were slightly lower than for the previous quarter and 9 per cent lower than for the corresponding quarter of last year. Since 1950 the net tonnage of vessels entering with cargo has increased yearly, the tonnage rise of foreign ships being greater than that of ships of the Commonwealth, the respective figures for the second quarter being 10 per cent and 5 per cent, compared with the same period in 1954. The clearances of foreign vessels compared with last year were lower by 3 per cent, while the total for the Commonwealth ships was 12 per cent lower.

## Technical Reports

*An Experimental Investigation of Stress Diffusion in Non-Buckling Plates.* By L. H. Mitchell, Ph.D. H.M. Stationery Office. Price 5s. 6d.—This report describes work done to provide experimental results for comparison with theoretical analyses of stress diffusion problems. Attention is concentrated on stress distribution near the ends of parallel strips of plate, symmetrical loads being applied by edge booms with continuous joints to the reinforced sheet. An outline of the existing theory is given and comparison made with the photo-elastic results.

*The Plastic Moduli of British Standard Rolled Steel Joists.* By M. R. Horne, M.A., Ph.D., A.M.I.C.E.—British Welding Research Association, 29, Park Crescent, London, W.1. Price 2s. 6d.—This booklet presents in tables the plastic moduli of R.S.J. sections, B.S.B 101 to 140 for bending about the major axis or the minor axis, thus dispensing with the use of the "shape factor" when designing on the plastic theory of structures. Reinforcement by plating joists is covered in the explanations and examples included.

*The Spot Welding of Aluminium and Its Alloys.* By J. E. Roberts, M.Eng., A.I.M., British Welding Research Association, 29, Park Crescent, London, W.1. Price 5s.—This report, printed on art finish paper and including photographs of various faults sectioned or radiographed, deals with materials, welding machines, surface preparation, joint design and the inspection of welds. Chemical cleaning solutions are dealt with in an appendix.

# Cargo Oil Tank Heating System

WIDESPREAD attention is being devoted to the subject of heating cargo oil tanks, and E. Green and Son, Ltd., of Wakefield, considers it reasonable to conclude that many existing systems are not satisfactory. Conditions have changed since unprotected steel coils could be used with a reasonable expectation of life, though the normal series system could never have been economical in the use of steam. Modifications to meet the increasingly severe corrosive conditions have been directed to the use of alternative materials for the coils, such as aluminium alloys in various forms, and there is much to be said for the use of cast iron. The corrosive conditions due to the presence of sulphur compounds in their various forms, with metal temperatures ranging between 100 deg. and 250 deg. Fah. are not greatly different from those arising in boiler plants, and it was realised by Edward Green more than 100 years ago that cast iron was the material most likely to ensure durability at reasonable cost. Recent researches have emphasised the correctness of this and have indicated the virulence of the corrosive action on unprotected steel surfaces where the temperature of the metal falls within the 220 deg. to 250 deg. Fah. range.

There are obvious difficulties in the use of cast iron pipe systems in ships, such as the need for care in alignment and fixing, and the danger of breakages and leaks, due to the working of the ship's structure combined with the movement of the pipes themselves with changes in temperature. Water-hammer action is not unknown and constitutes a further risk.

In seeking to effect improvements in the present practice, it appeared to E. Green and Son, Ltd., that there was considerable scope in two separate and distinct directions ; first, in the choice of suitable material, and, secondly, in the application and utilisation of the heating steam. For more than thirty years steel tubes protected by shrunk-on cast iron sleeves have been used successfully by the company to withstand the corrosive conditions encountered in boiler plant economiser practice, where similar sulphuric acid producing constituents are present. The technique of manufacture is well established, and within broad limits any suitable length of tube may be made, and it is convenient, but not essential, to use standard flanged-end joints. The advantages claimed for this system are that the cast iron shrouding, while giving complete protection to the steel tube, does not greatly diminish the flexibility of the steel inner tube, and that there is no need for careful alignment during installation, while the system will accommodate itself to movement of the ship's structure without imposing any strain on the flanged joints. The company has developed a heating system using steel tubes with cast iron sleeves, and the form of the external surface in contact with the oil has been determined after repeated trials, to secure the most effective proportion of outer heat-transmitting surface to the inner heat-absorbing area. The proportion of the outer surface being such that the heat given up by the condensing steam inside the tube can readily be transferred to the oil, and as the heating takes place entirely by convection, the gills must be so disposed that the convection currents are assisted to flow over the surface and not deflected away from it. The heat gradient is in the reverse direction to that in economisers, where heat is absorbed by the external surface from the hot gases and transmitted to the steam or water in the inner tube, and where the principal resistance to heat flow lies in the absorbed gas film on the external surface.

Periodical cleaning or brushing is necessary and from Fig. 1 it can be seen that the profile of the surface used is readily cleanable in every part. Comparative tests, it is stated, have shown that the heat transmitted to the oil per unit of external surface is actually slightly greater than that obtained with plain tubes, and it is believed that the probable reason for this result is that the projection of the heating gills into the liquid assists in the formation of stronger and unresisted upward convection currents.

Standard practice in the application and utilisation of the heating steam has been to connect all the heating pipes in any one tank in series, with a single steam inlet and a condensate discharge at the extreme end of the coil, either through a deck trap or to the main return line. The series arrangement is considered to be wasteful of steam, owing to the fluctuation in effective heat transfer. Since the steam condenses as it flows along the pipe, at the end of the pipe where it joins the exhaust riser the pipe is almost full of condensate and the transfer of heat from the waterlogged pipe is practically nil. The accumulated condensate cannot be discharged up the riser pipe and out of the deck trap until the steam in the riser has also condensed. When this occurs there is a massive discharge, and the heating effect returns to its original value, after which the same cycle of events occurs.

Under such circumstances the time taken to effect a given rise in temperature is longer than would be required with the heat transfer maintained at a maximum. A continuous drainage system has been adopted to meet these difficulties, and in the system the individual pipe runs extending fore and aft in each tank are connected in parallel to a steam inlet header attached to the forward bulkhead, with the pipes arranged to fall slightly towards the drain pots at the after end of each run. Each drain pot carries a dip pipe extending close to the bottom of the drain well, and the size of the dip pipe is so proportioned to the main pipe bore that only condensate water and not steam is discharged. The outlets from the drain pots are connected to a common exhaust header with a single outlet up to the deck trap or return line. In this way it is claimed that waterlogging is prevented, the discharge of the condensate as it accumulates in the drain pots is practically continuous, and the pipes themselves are always clear of water. It is possible, therefore, to reduce the steam flow or cut down the total heating time, but in either case an appreciable saving in steam must accrue.

To enable an approximate comparison to be made, the basis of present practice is to allow the same external heating surface as for a plain pipe system. The weight per square foot of surface, is stated to average about 13 lb. The company claims that the total weight and cost are appreciably less than the equivalent cast iron system ; the installation costs are much less, and the overall steam consumption compares very favourably with that of any series coil arrangement.

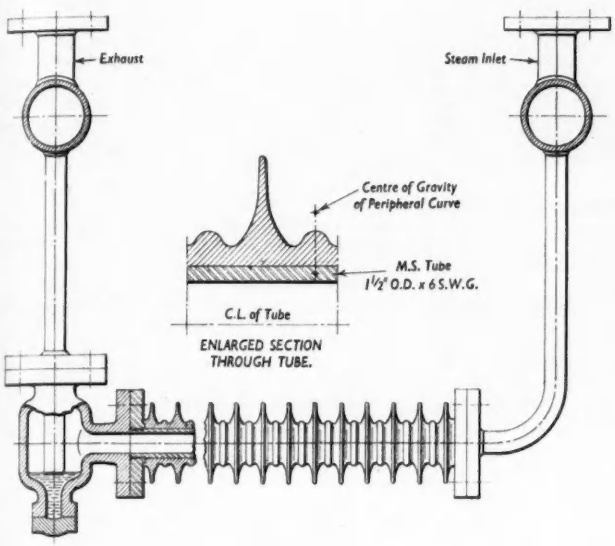



Fig. 1—Detail of C.I. protective tube for heaters

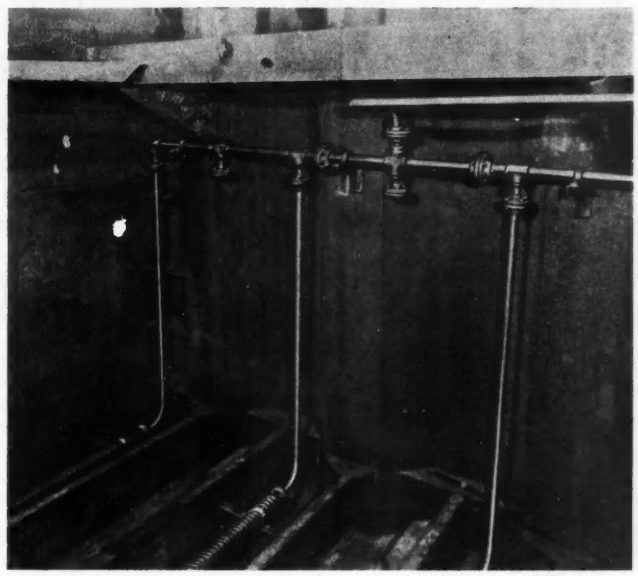


Fig. 2—Coils fitted in a cargo oil tank showing connection to steam supply

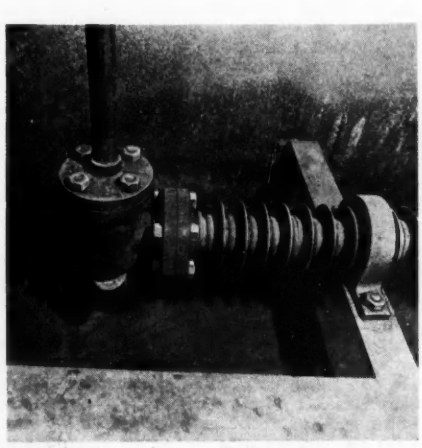


Fig. 3—End of coil showing drain pot and exhaust riser

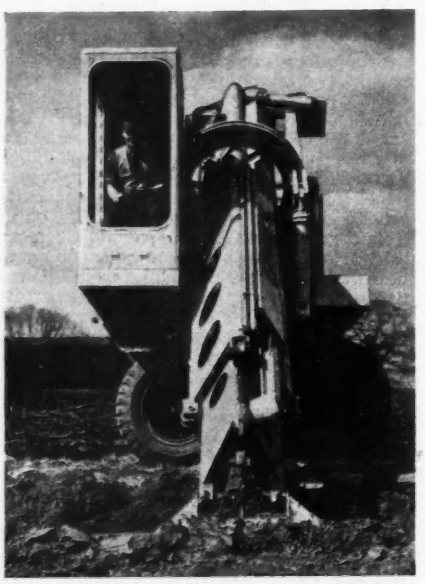
Ditch cleaning with a 2 cubic yard bucket, showing the action of the tool attitude control

## Versatile Earth-Moving Equipment

THE multi-purpose Gradall, now being marketed in this country by Blackwood Hodge and Co., Ltd., 11, Berkeley Street, W.1, has a range of uses transcending the earth-moving application. With a variety of buckets and scrapers it can dig trenches or square holes, grade levels or slopes, handle bulk minerals or trees and weeds. In addition, it does such unusual jobs as digging in tunnels and buildings with 11ft 6in headroom and removing the linings of furnaces while still hot. This virtuosity stems from its basic layout, its control system, and the provision of alternative configurations.

The boom is mounted on a 360 deg. turntable and luffs from 10ft below to 15ft above ground, and is arranged to twist through 90 deg. and to telescope from 12ft to 25ft long; the combination of the last two facilities enables straight sloping faces to be developed at an offset from the position of the plant, e.g. an open ditch can be dug from above the advancing end. A further control is afforded for the attitude of the bucket or other attachment, giving an angular range of 116 deg.; this can be seen employed in the first illustration and enables the operator to pull down saplings, prise out boulders or work through portals.

With the exception of travelling with the lorry-mounted version seen in the second picture, all actions are powered by a set of three hydraulic pumps driven by a General Motors two-stroke diesel mounted on the turntable; at 1500 r.p.m. two pumps give 40 gallons per minute each to lift and extend the boom, and a 15 gallons per minute unit supplies slew, tilt and bucket motions. A combined manifold and valve unit is mechanically operated from the control cabin; each control lever returns automatically to the stop position when released. Double-acting rams are supplied by flexible hoses; those for the turntable motion drive through sprocket chain, but working parts are relatively few. On machines intended to reach into hot furnaces special protection is provided for the hoses feeding the attachment control. On the crawler hydraulic motors on the superstructure drive the tracks by chains, a vertical shaft through the turntable, and a differential, the speed being ½ m.p.h. to 1 m.p.h. To steer, one track is locked by a sprag. The delicacy of the hydraulic system is claimed to allow earth surfaces to be finished plane within less than ¼in.



A lorry-mounted version, showing one of the two luffing rams and the tilt cylinder

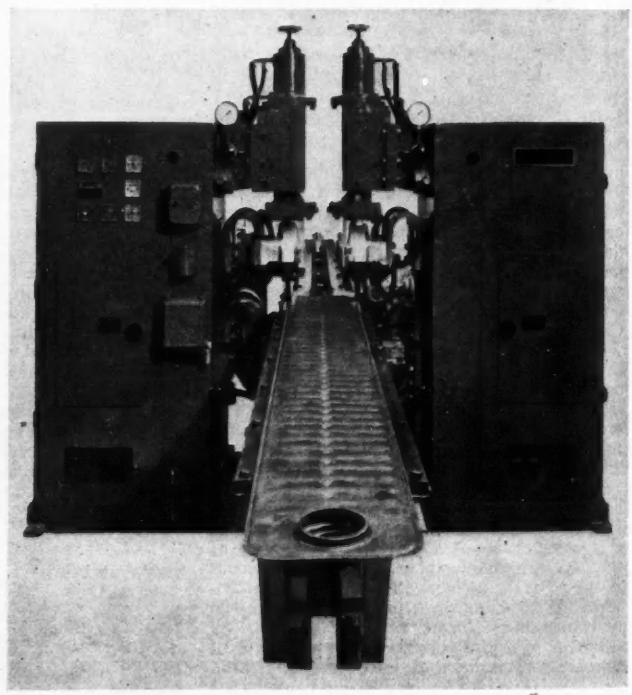
The bucket shown in our illustration can be reconnected to face directly downward in its extreme position, so that a vertical wall can be dug down to a square corner. Other attachments are scraper blades, ripping teeth for breaking pavements, offset booms to dig narrow trenches beside the machine, and extensions giving over 36ft reach. The standard truck carrier is a six-wheel chassis with walking beam rear suspension, either two or four wheels being driven; the frame is welded, and an optional extra is remote control to allow the carrier to be manœuvred from the superstructure instead of by a second crew member. It is interesting to note that the boom can be used to force any wheel of the chassis clear of the ground or to recover the vehicle if it becomes ditched.

## Continuous Seam Welding Machine for Long Components

A NEW conveyor drive seam welding machine for use on continuous production lines, which has been developed by Sciaky Electric Welding Machines, Ltd., Farnham Road, Slough, Bucks, is illustrated on this page. The machine is designed for installation at the end of a component production line and it welds two parallel seams simultaneously on long, flat components, such as panels, radiator sections, reinforced steel floor, wall or roof sections, steel doors, &c.

The two welding units of the machine are mounted facing one another on a common bedplate, with a central conveyor and guide assembly for the work between the units. If required, a machine can be supplied with a baseplate which can be extended and the right-hand unit made adjustable for position to accommodate components of different widths. Both of the welding units incorporate individual transformers and air pressure systems. The machine is completely automatic and its cycle is started by the depression of the starting push button for the conveyor drive after the component has been run on to the loading end. Seam welding of the component starts as the leading end of the component arrives between the electrode wheels, when the top pair of wheels automatically descend on the welding faces and the welding current is initiated. When the seams have been welded in the length of the component, the welding current is automatically switched off and the electrode wheels are raised clear of the welded faces. The component is then carried on to the discharge end of the conveyor and ejected from the machine.

The machine is equipped with a transformer having a rating of 150kVA at 90 per cent duty cycle, and its welding current is controlled by a synchronous ignitron with phase shift heat regulation. The welding pressure can be adjusted up to a maximum of 1000 lb and the speed of the conveyor can be varied between 3ft and 9ft per minute. Water cooling is provided throughout the machine.



150kVA automatic cycle, conveyor drive, seam welding machine for long components

The makers state that machines of this design can be supplied to weld more than two seams simultaneously; and in cases where a pressure-tight seam is not required a machine can be arranged for roller spot welding of components.

Fig. 1—De-icing grid fitted to "Ambassador" to spray water on to "Proteus" engine unit

## De-Icing Tests on Turbo-Prop Engine

TELEVISION techniques were used by the Bristol Aeroplane Company to expedite the proving of the de-icing provisions on the Proteus power plant intended for the "Britannia" airliner. The tests were carried out on a Proteus Mk. 705, (Figs. 1 and 2) in an Airspeed "Ambassador" ascending to freezing ambient temperatures. A tubular structure outrigged from the fuselage carried a group of thirty-seven nozzles facing the cowling of the port engine, the nozzles being supplied with water from a 135-gallon tank; the grid itself was protected from icing by a supply of hot air from the starboard engine.

Provision is made on the engine for heating the cowling with a mixture of cold air and exhaust gas from the high-pressure turbine, and for de-icing the compressor inlet guide vanes with hot air from the compressor. To observe the effectiveness of the latter a fan-cooled Pye television camera was mounted inside the nacelle to view the inlet guide vanes, and connected to a 14in screen in the cabin. When the anti-icing system was not in operation lumps of ice up to 3¼in by ¾in could be seen forming on and breaking off the vanes, and power fell off by up to 3 per cent; the severest deposits were disposed of within seconds of starting de-icing measures. The ability to observe conditions contemporaneously, instead of filming them and landing to process the record, enabled the trials to be completed in only twenty hours' flying.

To a large extent the success of the anti-icing measures is based on the configuration of the engine, the inlet guide vanes being at the rear of the compressor and remote from the air intake in the cowling. A later engine is to be tested with an increased heat supply to the compressor entry.

## By-Pass Jet Engine Type-Tested

A TYPE test has now been successfully completed by the Rolls-Royce "Conway" jet engine, rated at 13,000 lb thrust. As can be seen in the diagram, the low pressure compressor has two functions: it runs in series with the h.p. compressors, allowing a higher overall pressure ratio, and it also acts as a ducted fan to increase the mass of the slipstream. These effects improve the thermal and propulsive efficiencies respectively, and are reflected in the lowest specific fuel consumption attained by any type-tested jet engine.

The presence of an annulus of cool air around the engine is claimed to facilitate installation and fire protection, while the relatively low efflux velocity reduces jet noise. Engines of this nature may extend the application of jet propulsion to lower flight speeds, and four Conways are to be installed in the Vickers V.1000 military transport.

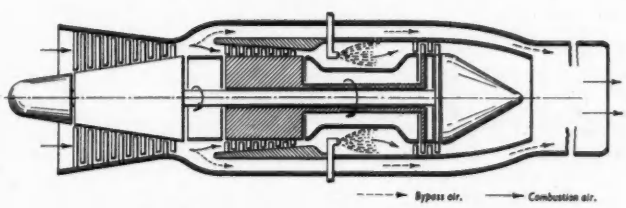



Diagram of a jet engine incorporating the by-pass principle

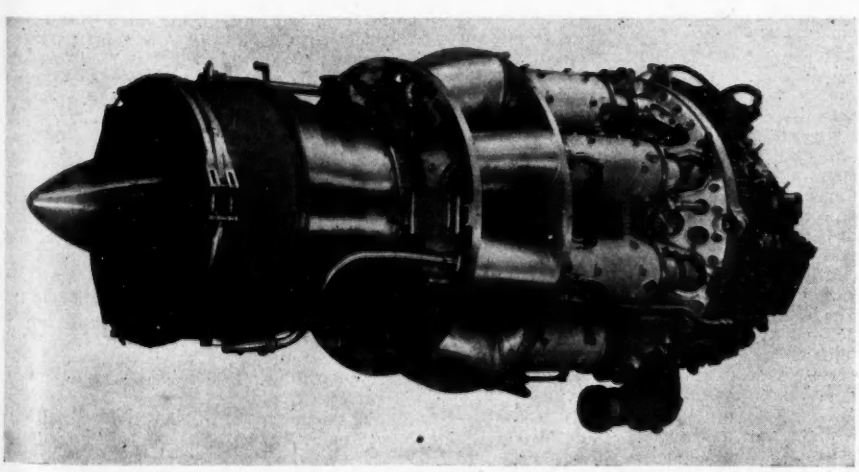


Fig. 2—A "Proteus" Mk. 705, showing the air intake passages between the combustion chambers

## Continental Engineering News

### Electricity in Belgium

Of a total annual power output in Belgium this year of some 1000 million kilowatt-hours, only 4 per cent are generated by municipal or other public authorities, 49 per cent of the total are generated by private electricity undertakings, while the remainder is supplied by various industrial enterprises for their own use. The considerable dispersion of the industry among a large number of producers has, it is alleged, led to the uneconomic retention of low-capacity plant, mostly around or under 50,000kW, with resulting high charges to the consumer. In an effort to counter this development the Belgian Government has introduced a national tariff (which decreases with increasing consumption). About 2000 million Belgium francs are to be spent annually on modernisation. Talks between the Federation of Belgian Industries, the electricity companies and the trade unions, have led to the setting up of a board to which belong representatives of the electricity companies and distributors. This board, which has thus been formed on the basis of a voluntary agreement, has, it is stated, far-reaching powers to co-ordinate production, investment, and the formulation of tariffs. Its task is to modify tariffs and to bring the charges to the level of other countries with similar economic conditions. Electrical power production in Belgium is at present carried out by 214 electricity works, of which 172 belong to factories.

### Refrigeration Society Congress

The German Association for Refrigeration (Deutscher Kälteverein) is holding a congress in Munich from October 13th to 15th. The programme has been provisionally fixed to include general and sectional meetings to deal with the following aspects: lubrication, free piston compressors, vertical spray cooling of air, industrial absorption systems, advances in techniques and instrumentation, problems of the brewing industry, storage of cold by means of ice, rural installations, developments of deep-freeze storage, basic refrigeration cycles, an automatic air liquefier with expansion, effect of low temperatures on the properties of materials, and new ways of cleaning ammonia. The congress will conclude with a social evening, and will be supplemented by visits and excursions. Applications should be made to Deutscher Kältetechnischer Verein, Karlsruhe, Hertz Strasse 16, Haus 35.

### Annual Meeting of Process Engineers

The annual joint meeting of the German Instrument Manufacturers (Fachgemeinschaft Apparatebau im V.D.M.A), the V.D.I. Process Control Section (Fachgruppe Verfahrenstechnik), and the Process Research Association (Forschungsgesellschaft Verfahrenstechnik) will take place in Munich from October 3rd to 5th. The programme comprises three general and seven sectional meetings, the latter to be held in parallel, with discussions following the lectures. Visits will be paid to industrial undertakings in Munich and its vicinity. Those interested should enrol with the Forschungsgesellschaft Verfahrenstechnik e.V., (22c) Leverkusen-Bayerwerk, German Federal Republic.

### German Automobile Production

Car production in the Federal Republic, already the world's third largest producer of motor vehicles and the second largest of passenger cars, has still further increased. During the first six months of 1955 the total of passenger and commercial vehicles and motor cycles produced amounted to nearly 440,000. This constitutes an increase of 20 per cent over the corresponding period in 1954, when annual production reached 670,000 units, or 32 per cent above 1953.

# Industrial and Labour Notes

### Economic Affairs

Last Saturday, the Prime Minister, Sir Anthony Eden, made a speech in which he commented, in some detail, on the country's present economic situation. The many things that the country was trying to do at once, he said, were straining its resources and increasing costs. Better roads, modernised railways, more houses, new schools, new power stations, capital expenditure in industry, the mines and on the land, and the development of nuclear power were among them. In those aims, the Prime Minister continued, there was nothing to criticise, but all of them made demands on our resources, and they could not all be met at once. None could be halted altogether, Sir Anthony said, but some must be restrained.

Sir Anthony went on to say that higher wages and higher profits could only be justified by higher production. Our greatest danger was to be priced out of the markets of the world because our productivity did not rise as fast as our costs. That, he emphasised, was a " mortal peril," and that was why industrial disputes such as had been experienced this year could be so serious in their consequences. But, the Prime Minister urged, a sense of proportion must be preserved. There was certainly no evidence, he said, of any widespread worsening of industrial relations. On the average, the time lost in industrial disputes in this country might be no more than in most others ; the difficulty was that we could not afford that loss so well. This country was far more vulnerable than its competitors, particularly when disputes affected the delivery of goods to the rest of the world. As had been seen in recent months, Sir Anthony observed, industrial disputes could be just as damaging and sometimes harder to settle when they were caused by disputes between unions as when they were about wages and conditions. He felt sure that the right way to tackle questions of industrial relations was not for the Government to try to rush in and impose some solution, but for all who were concerned — the Government, trade unions, employers and nationalised industries—to work it out together and see what could be done to reduce the risks of industrial disturbances.

### Industrial Disputes

According to the latest statistics issued by the Ministry of Labour, there were 109 stoppages of work through industrial disputes in progress in the United Kingdom during July. They included eleven stoppages which started before July. In these 109 stoppages, 34,700 workers were involved during July, with an aggregate loss of 88,000 working days. This was considerably below the high figure for June, when there were 159 stoppages, involving 98,000 workers and causing a loss of 1,332,000 working days.

In the first seven months of this year there were 1305 stoppages of work through disputes. The number of workpeople involved in them was 454,900 and the aggregate number of working days lost was 2,895,000. In the comparable period of last year there were 1142 stoppages involving 220,200 workpeople and causing a loss of 772,000 working days. This year, the most serious loss of time through disputes has been in the transport industries, the aggregate number of working days missed being 1,650,000, or about three times as many as in the first seven months of last year. In the coal mining industry, between January and July, 910,000 working days were lost through disputes, against 287,000 in the comparable period of 1954.

### Changes in Wage Rates

The Ministry of Labour has stated that changes in wage rates, which were reported as becoming effective in the United Kingdom during July, resulted in an aggregate increase of approximately £93,000 in the weekly full-time wages of 478,000 workpeople. In the first seven months of this year changes in wage rates have meant a net increase estimated at £4,201,000 in the weekly full-time wages of about 10,676,000 workpeople. That total includes £1,112,100 representing the extent of the weekly increases granted to 2,478,000 workers in the engineering, shipbuilding, electrical goods and vehicle manufacturing industries. At the end of July, the index of rates of wages (June 30, 1947=100) was 153 for all workers, compared with 152 at the end of April and 144 at the end of last year. In the first seven months of last year, there was a net increase of £2,455,000 in the weekly full-time wages of 7,841,000 workpeople.

### Wages and Dividends

Sir John Braithwaite, chairman of the Stock Exchange, has made a statement this week concerning the relative increases in wages and salaries and dividends. He says that misconceptions continue to arise about the relation between dividends, wages and company profits, mainly, he thinks, through the use of percentages without stating the total sums to which the percentages apply.

The statement goes on to say that any broad consideration of the matter must go back to the spring of 1948, when the late Sir Stafford Cripps, with the support of the T.U.C., called for restraint all round. The Federation of British Industries obtained from its members an agreement not to increase dividends for 1948, and again for 1949. The fact that wages and salaries rose by £1040 million, or 19 per cent, during the two years when dividend limitation was substantially observed, must be borne in mind, Sir John comments, in considering the rises in dividends that came later.

The total of wages and salaries for the year ended December 31st last, Sir John's statement continues, was £9265 million as against a total of £1122 million for interest and dividends quoted on the Stock Exchange—over eight times as great. Wages and salaries have advanced since 1947 by £3790 million (69·2 per cent) against an increase of £273 million (32·1 per cent) in interest and dividends, of which ordinary dividends constitute 39·6 per cent. That means, Sir John points out, that the rise in wages and salaries is more than double the rise in interest and dividends by percentage, and nearly fourteen times as much by volume. Company trading profits, Sir John adds, have risen since 1947 by £877 million (51·6 per cent) against the rise in wages and salaries of £3790 million (69·2 per cent) ; that is to say, that the rise in wages and salaries has been appreciably more than the rise in company trading profits by percentage, and four times more by volume.

### Railway Wages

At the end of last week, the Associated Society of Locomotive Engineers and Firemen stated that it had informed the National Union of Railwaymen that " no useful purpose " would be served by a joint meeting to consider the formulation of a new wage claim.

At the recent annual conference of the N.U.R. the executive of that union was directed to prepare a claim for increased wages. The N.U.R. executive, in its subsequent deliberations on the matter, decided that it would consult the two other railway unions with a view to a joint approach to the British Transport Commission, though it was agreed that the N.U.R. should proceed alone if the other unions were unwilling to participate. In its statement, the A.S.L.E.F. said that the history and chronicle of events clearly indicated that the many efforts to work jointly on wages questions had proved unreal. The A.S.L.E.F., the statement added, did not desire " to put obstacles in the path of any trade union," and therefore recognised the right of the N.U.R. to go forward with its own application. But the A.S.L.E.F. said that it would fashion its own policy " in accordance with the wishes of the member grades."

Meanwhile, the third railway union, the Transport Salaried Staffs Association, has made some observations on the suggestion of a joint approach. Its executive said that it was prepared to meet the N.U.R., though at this stage it was not committed to the immediate submission of a wage or salary claim.

### Coal Distribution

The general council of the Trades Union Congress has asked the Minister of Fuel and Power to urge the Government to make an inquiry into the structure, methods and costs of coal distribution from pithead to final consumer. The T.U.C. says that " because of numerous and persistent complaints from affiliated organisations about the gap between the pithead price of coal and the price paid by the consumer," the general council has been giving detailed consideration to the possibility of reducing this gap. In a study of the available information, particular attention was paid to the possibilities of narrowing the gap by reducing distributive margins and " increasing the efficiency of the distributive structure."

The T.U.C. goes on to say that available evidence suggests that there is waste in the present coal distribution system and that " large firms may well make net profits considerably in excess of what the Ministry of Fuel and Power fixes as a reasonable gross margin." It feels, however, that there is not enough information to enable specific proposals to be put forward. The T.U.C. general council is therefore of the opinion that only a full-scale inquiry into the structure, methods and costs of the existing organisation can provide the requisite factual basis for a detailed analysis of coal distribution problems. The general council's view is that a committee of inquiry should be given terms of reference which would allow a thorough investigation of all intermediaries and costs between the pithead and consumers, whether they be domestic or industrial. The T.U.C. adds that it considers the matter to be urgent, for, it says, " it would be wrong to allow part of the benefits of the National Coal Board's investment programme to be dissipated in an inefficient and wasteful distributive system."

### National Insurance and Occupational Diseases

In May, 1953, the Minister of Pensions and National Insurance appointed a committee, under the chairmanship of Mr. F. W. Beney, Q.C., to review the " diseases provisions " of the Industrial Injuries Act. In its report, which was published at the end of last week, the committee advises that the present system of prescribing specific occupational diseases, under the industrial injuries insurance scheme, should not be changed.

At present, a disease may be prescribed by the Minister of Pensions and National Insurance if he is satisfied that it ought to be treated as a risk of an occupation and not as a risk common to everyone, and that the attribution of particular cases to the nature of the employment will normally be possible with reasonable certainty. The committee considers that it would not be practicable to extend insurance cover to everyone who could show he was suffering from a disease which was probably of occupational origin, because, the report says, in the present state of medical knowledge many of the claims could not be decided on any reasoned basis. But the committee emphasises its conviction that the assiduous pursuit of research into occupational health hazards is essential to the effective working of the system of prescription, and mentions the importance of using statistical techniques for this purpose. The report recommends that the Industrial Injuries Advisory Council be made responsible for keeping under constant review the schedule of prescribed diseases, and for suggesting to the Minister diseases which might be prescribed, and research or investigations bearing on prescription which might usefully be carried out. To enable the council to discharge these responsibilities effectively, it is suggested that a small body of highly qualified specialist staff should be put at its disposal.

# The American Scene

BY OUR AMERICAN EDITOR

## End of Dixon-Yates

THE recent intense controversy over the Dixon-Yates contract to build a large steam power station has provided the Democratic party in America with what now appears to be its most promising issue for the presidential elections in 1956. Unless the Democrats are successful in their increasingly active search for deliberate, patent and official betrayal of the public interest by the Eisenhower Administration with respect to the Dixon-Yates contract, their indictment of this affair before the people will be factually limited to a series of amazing blunders in the Administration's handling of the scheme. They have not yet turned up criminal wrongdoing. But they have, by hard driving, exposed a record of fumbling, evasion and undue Administration pressure on behalf of the contract that should furnish good political ammunition in 1956. The controversy, which Senators Clinton Anderson, Lister Hill, Albert Gore and Estes Kefauver, and Representative Chet Holifield of California—all Democrats—have led in stimulating, arose from the following facts: (1) Last year President Eisenhower took the unusual step of personally ordering the U.S. Atomic Energy Commission to make a contract for constructing a 600MW steam power station with Dixon-Yates, a public utility combine formed for the purpose. The power was to be fed into the Tennessee Valley Authority system as a replacement for electric energy that would be subtracted from the system by new A.E.C. installations at Paducah, Kentucky. Only by this replacement could the T.V.A. meet the growing needs of the Memphis area which it serves. (2) The Atomic Energy Commission, being the only agency empowered by law to make lengthy commitments, had made power contracts during the Truman Administration with the Ohio Valley Electric Corporation and Electric Energy, Incorporated. But these were directly to fill its own requirements. Never before had the A.E.C. acted as the contracting principal for another Government agency. (3) The contract with the Dixon-Yates group was for 107,250,000 dollars, of which the financing was subject to the approval of the Securities and Exchange Commission. Congress was to provide an appropriation of 6,500,000 dollars for a transmission line through which the Dixon-Yates power was to be fed into the T.V.A. system. The advocates of publicly financed power generating schemes as opposed to private power supply instantly attacked the contract on ideological grounds, and also with the charge that it would increase consumption costs in the area. Special advocates of unlimited expansion of the T.V.A. joined them. On the other side were the President, who favours private power supply in any project which private companies can undertake and the communities which will be directly benefited will not; and who opposes expansion of the T.V.A. partly because its freedom from public taxation imposes its upkeep on taxpayers all over the country. Naturally ranged with him were those who subscribe to this ideology, and, of course, the private power industry also.

The hard fighting of 1954 against Dixon-Yates was resumed last February after the Administration's first major blunder. The President some months before, reacting to mounting Democratic attacks on the contract, had instructed the Bureau of the Budget to make public all the "pertinent" facts. Director R. R. Hughes omitted from this record all reference to the part played by Adolphe H. Wenzell, then an officer of the First Boston Corporation, as a Government consultant on the financing, explaining later that, since Wenzell had nothing to do with the making of policy, his participation was not "pertinent" to the narrative. Senator Hill told the Senate of the omission and said it was worse because the First Boston Corporation, a firm of investment bankers, was interested in the financing. The First Boston Corporation replied that neither it nor Wenzell would receive or accept a fee; that Wenzell's participation was at the request of the Government and "had long been known in Government, financial and utility circles." This did not at all satisfy the Democrats, and in the midst of the shouting, even the waiver of fees by the First Boston Corporation and Wenzell was forgotten by the critics. And afterwards Hughes, expanding his tactical vulnerability, told a sub-committee that he had no knowledge of the First Boston's relation to the financing which the corporation itself had explained publicly on February 22nd. Nevertheless, the Administration continued to carry all the effective votes in Congress for the Dixon-Yates project, and the Securities and Exchange Commission approved the financing. But then came another bad blunder. Two days before the House was to begin debate on the much-contested appropriation for the transmission line, and Wenzell was to appear before the S.E.C. to explain his part, the Assistant to the President, Sherman Adams, cut in, and he did so secretly. On the ground that Government lawyers had not yet decided whether to enter the Wenzell hearings, he asked Chairman J. Sinclair Armstrong of the S.E.C. to postpone them. All the commission members agreed but declined to give the reason; and the key vote carried in the House. But the Democrats discovered that the White House had played a part in the postponement, and yet another blunder swiftly followed. Chairman Armstrong declined to answer questions about the incident from a Senate sub-committee as an invasion of the Executive province by the Congress. This created such an impression of covering up something smelly that Armstrong was instructed to answer, and did. Meanwhile, the City of Memphis was completing the plan which gave the President an opportunity to cancel the troublesome Dixon-Yates contract and still maintain the position that induced him to order it drawn. Late in June when Memphis informed the T.V.A. it was going ahead, and the T.V.A. passed on the information, the President ordered the review and a simultaneous check on the capacity of Memphis to complete its project. That produced the fourth blunder—the use by the Attorney General of the F.B.I., known only to the public as concerned with heinous crime, to do the checking. This enabled the critics to cry "outrage." The President's order to cancel the contract quickly followed the production of bona fides by the mayor of Memphis which the President found satisfactory. Thus, the President had sustained his public versus private power policy. But the Democrats had made a bad compound word of "Dixon-Yates" and the contract they attacked was terminated. And the Democrats had also exposed grave errors of administration which—even if they develop as nothing more—should furnish them with useful campaign material in 1956.

Many American engineers do not share the opinion of the more ardent critics of the Dixon-Yates contract that this long-disputed project constituted "a national scandal," something akin to Teapot Dome. Teapot Dome was a "give-away" to private interests of rights to exploit a valuable piece of public property. No "give-away" of public property was involved in the Dixon-Yates affair. The questions at issue were whether private or public funds should build a needed addition to the power resources of the T.V.A. area, and on what terms. These were questions upon which reasonable men could and did differ. Mr. Dixon and Mr. Yates, being champions of the private power theory, sought an opportunity to turn the need for additional power to the advantage of their own companies by earning an additional profit. No charge of wrongdoing could be brought against them on this ground. There is nothing dishonourable in the desire of a private corporation to expand its profits. As for the terms of the contract itself, there is certainly room for argument, but, since these terms were publicly announced there is no reason for charges of "skullduggery." At the same time, there were factors which cast doubt on the wisdom of this scheme from the broader view of public policy. In the first place, it seemed that the question of how to provide for the additional power needed was a matter in which the initiative should have been taken by the T.V.A. itself and not—as events transpired—by the Atomic Energy Commission, which was the customer requiring the additional power. In the second place, it has become increasingly evident that the whole record of the discussions that preceded the decision was not originally made public, as it should have been. And finally, there is ground for believing that at least in some quarters the Dixon-Yates contract was intended to be a first step in dismantling the T.V.A. of its functions in the field of power production and limiting it essentially to activities of flood control and navigation. Such a transformation would run counter to the long-established policy of Congress. For these reasons many American engineers welcome the action of the President in cancelling the contract. He had a sufficient reason for doing so once the city of Memphis announced a firm decision to build for itself the facilities needed to generate the power it requires.

## Commercial Application of Nuclear Power

THE Foster Wheeler Corporation, of New York, has announced that it is ready to design and build, for completion by 1960–1961, the first large-scale American nuclear power plant utilising the aqueous homogeneous power breeder system. Such a plant, with an electrical capability of 100MW, has been offered to the industry at an estimated cost to the owner of 21,000,000 dollars—a price within range of some conventional power station costs. The company's varied experience in the nuclear energy programme, as well as detailed technical studies and cost estimates undertaken in connection with twenty-eight different reactor systems, led to the decision to design and construct complete plants utilising the homogeneous reactor principle now. The design work for the aqueous homogeneous power breeder is based on the

successful operating experience of the U.S. Atomic Energy Commission at Oak Ridge with a homogeneous reactor experiment which has clearly demonstrated the essential simplicity, operability and controllability of a homogeneous reactor.

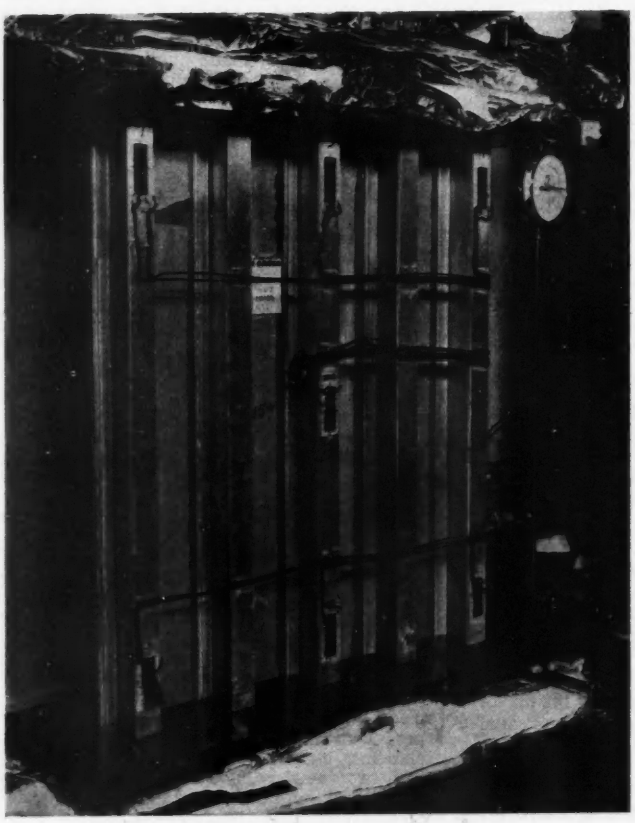
The homogeneous power breeder has been recognised in America as one of the two reactor systems which hold the most promise of eventually competing with conventional power systems. The aqueous homogeneous power breeder system has many inherent advantages. It uses a liquid fuel, and is self-controlling to the extent that, as demand on the steam generators increases, the reactor responds by releasing the heat required. Specifically, this is accomplished through expansion of the fuel, which tends to decrease the amount of uranium in the core. Additional regulation is provided by controlling the concentration of uranium in the fuel solution. An important aspect of the reactor is safety. The amount of fuel in the aqueous homogeneous core system is always consistent with the amount required for operation, because it can be added continually to the system to replace the fuel that is burned. To guard against hazards due to leakage, every piece of equipment containing radioactive material is enclosed in a separate, secondary vessel that will contain any leak. Simplicity of operation and accessibility of the equipment are particularly valuable aspects of the plant. Although designed for minimum maintenance, every piece of equipment is readily accessible for maintenance or repairs without excessive radiation hazard. The steam produced by the reactor system can be used to run a conventional turbo-generator.

The reactor system utilises a spherical core containing a solution of uranyl sulphate in heavy water in which the fission of uranium 235 generates the heat required. The fuel solution is pumped through the core to steam generator heat exchangers in which saturated steam at 600 lb per square inch is produced by the heat the fuel solution gives up. The dimensions of the core vessel are such that the fuel solution becomes critical as it circulates through the vessel. In order that the equipment be practical and of manageable size, four heat exchangers are used; this also permits any of the heat exchangers to be isolated for servicing when necessary. Four canned rotor pumps are used to circulate the fuel through the core and through the heat exchangers. The core is connected to a system of non-critical dump and storage tanks. The solution may be drained out of the reactor system into these tanks, when desired, for shut-down and maintenance purposes. This dumping arrangement is controlled by a hydraulic pressure balanced system to eliminate large valves. A separate vessel connected into the highest point in the system serves as a pressuriser and surge tank. The desired operating pressure of the system is maintained by electrical heaters in the pressuriser. Breeding is accomplished in a blanket of fertile material contained in a spherical vessel surrounding the core vessel. The fertile material will be thorium 232, which is converted to uranium 233 in the breeder blanket. The uranium is used to refuel the reactor. The thorium in the breeder blanket, in heavy water, is pumped through the blanket vessel. Approximately 17 per cent of the total reactor heat output is generated in the blanket. Two heat exchangers are used to extract the heat from the blanket material and to generate additional steam at 600 lb per square inch. Two canned rotor pumps circulate this material through the blanket and through the heat exchangers. The blanket circuit is connected to a dump tank similar to that used for the core. The pressuriser in the core circuit is also connected to the blanket circuit to maintain essentially equal pressures in both circuits. A reprocessing system for the core material is included in the plant, to remove the majority of the gaseous and insoluble fission product poisons as they are being formed in the fission process. The blanket material is periodically removed for reprocessing in an existing Government plant. It is anticipated that when reactors of this kind are operating it will prove feasible to have a centrally located commercial reprocessing plant for the blanket material to serve ten reactors.

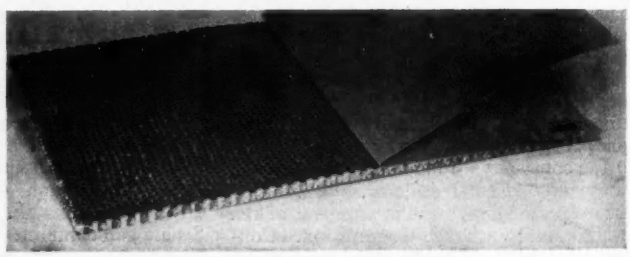
The Foster Wheeler Corporation at present has a contract to design and manufacture two of the four steam generating units to be installed in the 60MW nuclear power station of the Duquesne Light Company at Shippingport, Pennsylvania. This contract augments a series of nuclear projects completed by Foster Wheeler since the inception of the American Atomic Energy programme, which included the steam generators for the U.S.S. "Nautilus" and its land-based prototype at Arco, Idaho; several unusually large stainless steel heat exchangers for use in the production of nuclear materials, and the design of a fuel reprocessing plant at Arco which has been operating successfully for several years.

# Bonding of Aircraft Structures

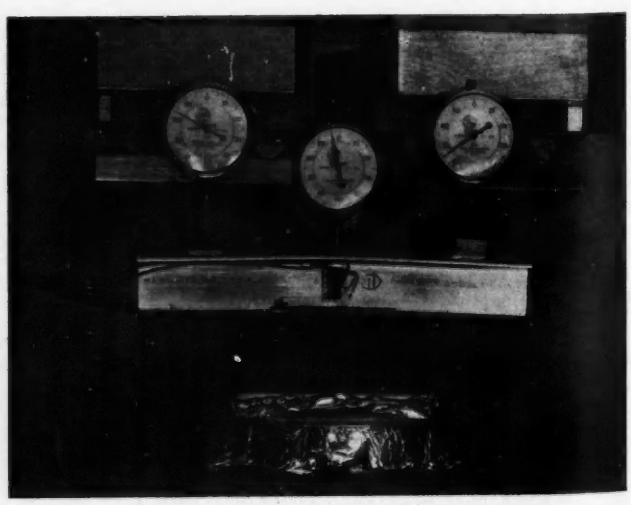
THE development of high-strength metal-to-metal adhesives in recent years has made possible an entirely different approach to the fabrication of metal aircraft structures. Certain economic, structural and weight-saving advantages offered by the substitution of adhesives for rivets have already been realised by several American aircraft companies in the fabrication of structural components, and the widespread adoption of this method in the future has become a definite possibility. To secure a better understanding of the behaviour of adhesive-bonded aircraft structures, the National Bureau of Standards recently conducted investigations under the sponsorship of the National Advisory Committee for Aeronautics and the U.S. Navy Bureau of Aeronautics. The use of adhesives for bonding aircraft structural components is not new. During the first world war casein was used in the gluing of wooden aircraft structures. The synthetic glues were used extensively for many all-wood and some wood-metal joints for aircraft in the last war. Finally, the development of high-strength resin and resin-rubber adhesives



Bonded sheet-stringer panel undergoing axial flat-end compression test



Aluminium honeycomb sandwich panel



Bonded sheet-stringer panel undergoing bending test with load applied centrally between angle supports

made possible the bonding of all-metal aircraft structural components. Two such components are the sandwich panel and the sheet-stringer panel.

A sandwich panel consists of three laminations bonded together. The outer two laminations, or facings, are made of strong, stiff sheet materials which usually determine the elastic and strength properties of the panel. The central layer, or core, is made of a light material and serves only to separate the facings and to restrain them from becoming elastically unstable. The value of sandwich construction lies in its relatively light weight and in the high bending strength and stiffness it possesses as a result of its high ratio of cross-sectional moment of inertia to weight. Another advantage, from the aerodynamic standpoint, is the absence of rivet heads. One of the applications of sandwich construction is in the fabrication of skins and floors for pressurised aircraft fuselages where the sandwich construction is subjected both to lateral pressures and to axial loads simultaneously. The engineering mechanics laboratories of the N.B.S. conducted an investigation for the N.A.C.A. to determine the strength of sandwich panels of various thicknesses under these combined axial and lateral loads. The panels tested were about 30in long and 17in wide, with facings of either 0·025in or 0·032in "75S-T6" aluminium alloy sheet, and cores ½in or ¾in thick. The cores were honeycombs of 0·005in "2S-H" aluminium foil and had a density of only 6·54 lb per cubic foot. The lateral pressures were applied by a rubberised fabric air bag and ranged from zero to 9·54 lb per square inch. The panels were simply supported in knife-edge seats in a hydraulic testing machine which applied the axial load. All tests were carried to failure, and strain and deflection measurements were made periodically with "SR-4" wire strain gauges and dial gauges, respectively. The results of these tests were compared with values predicted from a theoretical analysis based on column theory. The analysis includes the effects of the strain energy stored in the faces of the panels by extension and by bending, and in the core by shear, but disregards the strain energy due to shear in the faces and to extension in the core parallel to the faces. Good agreement was obtained between theory and experiment for the flexural rigidity and for the failing loads under the various load combinations investigated. The theory was found to be conservative, however, in its prediction of axial strains and lateral deflections. The discrepancy was attributed to anticlastic bending, which was observed in the tests but does not enter into the column theory. Anticlastic bending produces a transverse curvature in a panel which increases its stiffness and thus reduces the strains and deflections for a given loading condition. The amount of anticlastic bending obtained in a panel increases with the lateral load and decreases with panel stiffness. Hence the agreement between experiment and theory was considerably closer for the stiffer panels tested and for the panels tested under the lesser lateral pressures. For a panel tested with zero lateral pressure, the agreement was excellent.

When a sandwich panel is attached to some other structural member, it may be necessary to transfer the loads from the member to the panel by means of a pin that fits into a reinforced hole in the panel. As part of an earlier research project conducted by the Bureau for the U.S. Navy Bureau of Aeronautics, a test was performed on a sandwich panel to determine the stress distribution near a reinforced circular hole in the panel that was loaded by a pin. The results indicate that if the reinforcement is bonded to the sheet so that reinforcement and sheet act as an integral unit, then plane stress theory will predict the average elastic stresses in both sheet and reinforcement and the changes in the hole diameter.

A more conventional class of aircraft structure to which adhesives have been applied is the sheet-stringer panel. Sheet-stringer construction, which comprises most of the outer skin of a conventional aircraft, consists of a sheet with stiffeners attached longitudinally to one side. The sheet provides the necessary aerodynamic contour while the stiffeners, or stringers, add the necessary strength, stiffness and stability. The stringers often are angles or channels, but very frequently have cross-sections resembling "Z," "I" or "hats." In the past, the stringers were almost always riveted to the sheets. Two recent innovations are the bonded sheet-stringer panel and the integrally machined sheet-stringer panel. The Bureau tested twenty-one riveted and bonded sheet-stringer panels for the N.A.C.A. to determine the relative merits of these two methods of construction. The panels were fabricated from "75S-T6" aluminium alloy with five stringers each, spaced at 3½in intervals. Nine panels were riveted with a 1½in pitch, nine were bonded with an epoxy resin adhesive and three were bonded with a phenolic resin-rubber adhesive. Some of the panels were tested in flat-end compression, others in compression with a concentrated load applied to one end of the centre stringer, and the remainder in bending with a concentrated load applied centrally between simple supports. The results obtained in the tests show that the mechanical properties of both types of panels are comparable. The choice in any particular case would depend upon the specific designs being compared.

The primary advantage of bonded sheet-stringer panels over conventional panels which have one line of rivets per stringer, is the increased sheet stability that is obtained by bonding. The broad area of attachment between sheet and stringers reduces the unsupported width of sheet, thus increasing the load necessary to produce buckling of the sheet between stringers. When buckling occurs, the broad area of attachment between the sheet and stringers provides a greater effective sheet width. In addition, inter-rivet buckling and stress concentrations near the rivet heads, which tend to produce buckling between stringers, are eliminated. The primary disadvantage of bonded sheet-stringer panels seems to be in the mode of failure in flat end compression. When maximum load was reached in the tests, the bonded panels experienced almost complete destruction. The failure of the riveted panels, on the other hand, was confined to local buckling of sheet and stringers between the rivets. One of the more important factors restricting the universal acceptance of adhesive bonding for aircraft structures is the difficulty of properly inspecting bonded joints. Small changes in pressure, temperature, humidity, &c., in the fabricating process can produce imperfections which greatly decrease the strength of the joint and can often be detected only by destructive tests. These imperfections can be dangerous in modern high-speed aircraft which are designed with extremely high operating stresses. It is, therefore, believed that the widespread application of bonding techniques is dependent upon the development of either completely reliable fabrication procedures or of satisfactory non-destructive inspection procedures.

## Nuclear Reactor for Medical Treatment

THE first American nuclear reactor specifically designed for medical treatment and research will be built for the Medical Centre of the University of California at Los Angeles by the Nuclear Engineering and Manufacturing Division of North American Aviation, Incorporated, of Los Angeles. The new reactor will produce gamma rays and neutrons for cancer therapy, and has been designed to serve also a variety of additional medical and non-medical uses, including the production of radioactive isotopes and radiation for the experimental sterilisation and preservation of food and drugs by nuclear energy. The reactor, which is expected to be completed within one year, also will be available for use by the U.S. Atomic Energy Commission in conjunction with the Atomic Energy Project at the university, where both classified and unclassified research in biology and medicine is being carried on. The pile, which is shown diagrammatically in the accompanying illustration, will be installed in a new underground wing of the Medical Centre. Designed to operate at a power level of 5kW, with a maximum power of 50kW, the medical reactor will produce a high intensity of neutrons. The gamma rays to be produced by the reactor will be of greater intensity than those produced by 50 lb of radium.

The reactor fuel is to be obtained on loan from the A.E.C. and will consist of about 4 gallons of uranyl sulphate solution, highly enriched in uranium 235, which will be contained in a 1ft diameter stainless steel sphere or core. The core will be situated inside a 5ft by 5ft by 8ft stack of graphite bars, shielded by 5ft of high-density concrete. Radiation ports will lead from the core to a patient treatment room, a laboratory, and another room where research on animals can be performed. An access port will permit materials to be irradiated in a channel leading inside the core itself where radiation will be the strongest. The underground reactor wing housing the complete installation will be about 45ft wide, 60ft long and 27ft high. The rate of fission of the pile will be adjusted by control rods made of boron, which can be moved in and out of the core area. The solution reactor will be self-contained with no radioactive particles, fumes or smoke being exhausted into the atmosphere or public disposal systems.

Either gamma rays or neutrons can be obtained from the reactor for cancer treatment. While both are radiated from the reactor during the fission process, gamma rays or neutrons can be selected by the use of special shielding equipment between the patient's room and the reactor core. The size of the radiation port can also be varied to provide radiation in the required amounts or intensities. The gamma rays may be used to bombard malignant tissue directly. The thermal neutrons may be used in conjunction with certain injected chemicals to cause powerful but localised secondary releases of radiation within the cancer tissue itself. This use of neutrons, which is available only in reactor therapy, is thought to have a distinct advantage over X-ray and other forms of radiation therapy. There is evidence that a greater selective absorption of radiation by malignant tissue occurs with less damage to surrounding healthy tissue. An example of a kind of cancer that will be treated by this form of therapy is the glioblastoma multiforma, a brain tumour that infiltrates through healthy brain tissue. Preliminary studies at the Atomic Energy Commission's Brookhaven Medical Laboratories indicate that when borax is injected into a patient with this cancer, boron from the compound concentrates in malignant tissue. When the cancer area is bombarded with neutrons the boron captures neutrons. This causes a nuclear reaction in the boron, thus releasing powerful alpha particles. The alpha particles bombard the malignant tissue and destroy it, but are absorbed before they reach nearby healthy tissue. This and similar approaches give hope that with the new medical tool many such deep-seated cancers can be treated without damaging healthy tissue.

It has been emphasised that the new reactor will not be available for clinical use for at least two years after it is completed. In addition to clinical application of the reactor, the university is planning an extensive research programme, which will include radiation genetic studies, concerned primarily with the mutation effects of radiation. Other studies will include the manner in which radioactive materials are deposited in human bones, and neutron effects on tissue, particularly the lens of the eye. Most of this part of the programme will be directed to a better understanding of mechanisms of radiation effects and the counteraction of neutralisation of the deleterious reactions. A great deal of work will be done to set standards of safe practice. The university also plans to conduct a wide training programme with the reactor. This work will include the instruction of medical students, health physicists and others in techniques of reactor operation and utilisation of neutrons, gamma rays and pile-produced isotopes.

The experimental use of radiation from nuclear reactors to preserve and sterilise foods and drugs is also considered to be a promising field which is expected to lead to revolutionary processing methods. Research in this field has already demonstrated the possibility of increasing the "fresh" life of meat, vegetables and dairy products by atomic radiation. The use of radiation sterilisation in the pharmaceutical field also offers a number of benefits. For example, sterilisation processing requiring high temperatures which often reduce the strength and effectiveness of drugs might be replaced by radiation processing at room temperature.

# Personal and Business

## Appointments

MR. LEWIS DOBSON has joined the sales staff of Transport Vehicles (Daimler), Ltd., Coventry.

ALUMINIUM LABORATORIES, Ltd., Banbury, Oxon, states that Mr. A. W. Brace has been appointed to take charge of the surface finishing department of its chemical division.

MR. WALTER GRAINGER and Mr. John Mayer have been appointed joint managing directors of International Combustion (Holdings), Ltd., 19, Woburn Place, London, W.C.1.

THE BRITISH TRANSPORT COMMISSION announces the following appointments :—Captain S. Baxter Wright, dockmaster, Swansea docks ; Mr. G. W. Spooner, dock engineer (civil), Port Talbot docks.

THE ROYAL MAIL LINES, Ltd., announces that Mr. H. P. Wheeler has been appointed Commodore Chief Engineer of the company's fleet in succession to Mr. W. W. Simpson and will serve in the " Andes."

BRITISH CENTRAL ELECTRICAL COMPANY, Ltd., 6–8, Rosebery Avenue, London, E.C.1, states that Mr. C. G. Marks has been appointed managing director, additional to his duties as secretary of the company.

THE SHEEPBRIDGE GROUP announces the appointment of Mr. A. E. S. Gourley as technical sales representative in Scotland. His address is 46, Hazelwood Avenue, Newton Mearns, Renfrewshire (telephone, Newton Mearns 3267).

THE BLUE FUNNEL LINE announces that Mr. A. G. Arnold, who has been deputy chief superintendent engineer since 1946, has been appointed chief superintendent engineer in succession to Mr. L. C. Baker, who has resigned to become general manager of Hamworthy (B.C.E.) Ltd.

MR. FRANK SPENCER, a director of Opperman Gears, Ltd., Newbury, and managing director of The Hotpoint Electric Appliance Company, Ltd., is shortly relinquishing the latter office to become executive director of Opperman Gears, Ltd., concerned particularly with that company's future development. Mr. Spencer will remain a director of The Hotpoint Electric Appliance Company, Ltd.

THORN ELECTRICAL INDUSTRIES, Ltd., announces the following appointments to the boards of its subsidiary companies :—Ferguson Radio Corporation, Ltd., Mr. S. T. Holmes, Mr. C. E. Payne, and Mr. W. T. White ; Lamp Presscaps, Ltd., Mr. A. J. Ford ; Manifold Machinery, Ltd., Mr. A. J. Ford and Mr. G. Sparrow ; Smart and Brown, Ltd., Mr. D. A. Neill, Dr. J. W. Strange and Mr. G. J. Strowger.

THE LONDON MIDLAND REGION OF BRITISH RAILWAYS announces the following appointments :—Mr. A. H. Emerson, assistant electrical engineer (modernisation) ; Mr. R. W. Bailey, assistant to general manager (productivity and work study) ; Mr. J. S. S. Davis, assistant signal engineer, Euston ; Mr. J. R. Sampson, district operating superintendent, Preston ; Mr. A. M. Fairhead, district motive power superintendent, Chester ; Mr. K. S. Martin, district engineer, Derby North.

THE BRUSH GROUP, Ltd., announces the appointment of Mr. D. W. Mansell as sales manager of The National Gas and Oil Engine Company, Ltd., Ashton-under-Lyne, and a director of National Oil Engines (Export), Ltd. He is at present vice-president of Brush Aboe, Inc., New York, in which office he is to be succeeded by Mr. A. A. King. Mr. F. B. Langley, a director of National Oil Engines (Export), Ltd., is to become London manager of The National Gas and Oil Engine Company, Ltd. Mr. D. M. Muirhead is to take responsibility for the engine sales of Associated British Oil Engines (Export), Ltd., in the Far East.

VAUXHALL MOTORS, Ltd., Luton, announces changes in its organisation, as follows, to obtain more effective co-ordination between the factory technical departments :—Mr. F. V. Barker, director of manufacturing, takes responsibility for the production, production control, and standards departments ; Mr. H. T. Johnson, director of planning and facilities, is responsible for the forward planning, production engineering, sheet metal production engineering, and plant construction and maintenance departments ; Mr. A. J. Peppiatt, acting chief inspector, will report directly to Mr. J. R. Pearson, executive assistant to the managing director.

## Business Announcements

THE BRUSH GROUP, Ltd., states that an agreement has been made whereby Brush high-voltage switchgear will be assembled and sold in Australia by Electric Control and Engineering, Ltd., Sydney.

MATTHEW HALL AND CO., Ltd., Dorset Square, London, N.W.1, states that its telephone number is now Paddington 1212.

HEENAN AND FROUDE, Ltd., Worcester, states that its telephone number has been changed to Worcester 3461.

MILLSPAUGH, Ltd., Alsing Road, Sheffield, 9, states that its telegraphic address is now " Millspaugh Telex Sheffield."

TACOL LTD., which was formed last year by Mr. C. J. Wright, is to advise the Government of Iraq on its oil refinery development programme.

ADVANCE MOTOR SUPPLIES, Ltd., states that its Glasgow branch has been moved to 374–376, Argyle Street, Glasgow (telephone, Glasgow Central 2758).

THE CAPE ASBESTOS COMPANY, Ltd., announces the retirement of Mr. J. Gilmour Galloway, its marine representative, after twenty-seven years' service.

THE LANCASHIRE DYNAMO GROUP states that Mr. F. H. Schroeder, director of Lancashire Dynamo Holdings, Ltd., is making a tour of Central and South America and the Caribbean.

THE LOCKHEED HYDRAULIC BRAKE COMPANY, Ltd., and Borg and Beck Company, Ltd., state that manufacturing and selling licences have been granted to Automobile Products of India, Ltd., Bhandup, Bombay.

THOS. W. WARD, Ltd., Sheffield, has acquired the controlling interest in Alexander Metal Company, Ltd., Broad Lanes, Bilston, Staffs. Mr. H. W. Secker, chairman of Thos. W. Ward, Ltd., has been elected chairman of Alexander Metal Company, Ltd.

WELMEC CORPORATION, Ltd., states that, owing to the damage caused by fire at its offices at 147, Strand, W.C.2, it has moved to Maypole House, 27–28, Finsbury Square, London, E.C.2 (telephone, Monarch 9683 ; telegrams, " Welmcor London Telex ").

BOWDEN (ENGINEERS), Ltd., Victoria Road, Willesden Junction, London, N.W.10, states that it now holds the distribution and selling rights to the aircraft industry of " Toplock " tubing manufactured by United Flexible Metallic Tubing Company, Ltd., Enfield, Middlesex.

LONDON TRANSPORT states that Mr. A. H. Grainger, member of the executive responsible for railway engineering, and Mr. A. W. Manser, chief mechanical engineer (railways), have left for a six weeks' tour of the U.S.A. and Canada to visit railway installations and study railway engineering methods.

HENRY PELS AND CO., Ltd., 32–38, Osnaburgh Street, London, N.W.1, and Industrie-Werke Karlsruhe, A.G., Karlsruhe, have signed a long-term agreement by which all Pels machines and equipment, whether manufactured in this country or Western Germany, will be handled by both firms or their respective agents in all parts of the world.

MR. HAROLD JEANS has retired from the chairmanship of Industrial Newspapers, Ltd., publishers of *Iron and Coal Trades Review*, *The Foundry Trade Journal*, and other trade and technical periodicals. Mr. Jeans was editor of *Iron and Coal Trades Review* from 1907 to 1926, was elected a director of Industrial Newspapers, Ltd., in 1926, and has been chairman since 1931.

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, states that it has established five specialised divisions, as follows :—Works division, in charge of Mr. T. K. Hargreaves ; general contracts division, in charge of Mr. C. Ingman ; gas plant division, in charge of Mr. T. H. Riley ; chemical plant division, in charge of Mr. P. M. K. Embling, and blast furnace division, in charge of Mr. D. R. Brown.

## Contracts

BRUSH BAGNALL TRACTION, Ltd., Loughborough, has received a further order from the Steel Company of Wales for three $B_0$–$B_0$ diesel-electric locomotives of 660 h.p.

THE ENGLISH ELECTRIC COMPANY, Ltd., has received, through the Crown Agents, an order from the Malayan Railways covering twenty main line 1500 h.p. diesel-electric locomotives. The value of the contract is approximately £1,500,000. The locomotives, which will haul express trains up to 450 tons in weight on the Singapore–Kuala Lumpur–Prai line, weigh 96 tons each and are of the $C_0$–$C_0$ type, embodying the English Electric " 12SVT " diesel engine, which is rated at 1500 h.p., 850 r.p.m.

## Miscellanea

MR. A. AITKEN.—It is with regret that we record the death of Mr. Alexander Aitken who has been the superintendent engineer of the British Tanker Co., Ltd., since 1952.

SHIP COLOUR SCHEME.—The British India Steam Navigation Company announces that it has decided to change the colour of the hulls of the company's passenger ships from black, which has been used for nearly a century, to white.

ROLL DAMPING FINS.—We have received from Vosper Ltd. a brochure dealing with roll damping equipment, which the company produces mainly for small craft. The matter is treated technically and there are photographs of the gear, for which it is claimed that an 80 per cent reduction of roll has been achieved.

ECONOMICS OF ARC WELDING.—A brochure with the title " Economics of Arc Welding " has been issued by the Quasi-Arc Company, Ltd., and deals with the estimation of costs and a variety of factors which affect the economy of any arc welded construction. It examines the mechanics of costing, including charts relating to costs and estimating, and gives notes upon design and fabrication.

AUTOMATIC TRANSMISSIONS.—At the laying of the cornerstone on August 24th for the new factory of Borg-Warner, Ltd., at Letchworth, Herts, Mr. Robert S. Ingersoll, vice-president of the Borg-Warner Corporation, Chicago, forecast that when production commenced the output of automatic transmissions for road vehicles would be greater than that of any plant outside North America.

EXCHANGE PLAN.—We are informed by W. H. Dorman and Co., Ltd., of the initiation of a new site exchange plan for the home market covering diesel engines of the company's manufacture. Owners of engines of the DWD, DL, LA series and 6KA, 4BK 11, 4AJ and 4DS models ready for major overhaul may exchange them for a factory tested service engine. This plan means that the plant is only out of action for a short time and the cost is about half that of a new engine.

INSTRUMENT COMPONENTS.—Kelvin and Hughes, Ltd., states that many of the components which are used in the company's marine and industrial instruments can now be manufactured to suit special requirements. The list of components now available includes instrument motors, barometric capsules, " teletorque " synchronous transmission units, ultrasonic magnetostrictive oscillators, sine/cosine potentiometers, gyroscopes, optical components, and magnetic recording heads.

OBITUARY.—We have learned with regret of the death, on August 22nd, of Mr. H. G. Faull, who, until his retirement recently, was a local director of Thos. W. Ward, Ltd., Sheffield. Mr. Faull, who was sixty-eight, had been in the company's service for fifty-three years. We have learned, also, of the death of Mr. William Town, of Halifax, which occurred on August 20th at the age of seventy-three. He was co-founder, with his father, of the firm of Frederick Town and Sons, Ltd., Gibbet Street, Halifax.

DUST COLLECTION.—A booklet has been produced by Mancuna Engineering, Ltd., Denton, Manchester, describing the contribution of their multi-cyclone separators to the overall problem of dust collection. The booklet begins with an intriguing particle size chart which indicates methods of measurement and separation, and continues with a documented description of the "Microclone" and "Dustex" separators for volume flows up to several thousands of cubic feet per minute. Emphasis is laid on applications in which the recovered dust is valuable.

TITANIUM ALLOYS.—As a result of lengthy experiments and experience with pilot plants, a new melting plant for the production of titanium alloy in quantity is being built at the works of William Jessop and Sons, Ltd., Brightside Works, Sheffield, 9. The pilot plant was suitable for melting 6in diameter ingots up to 40 lb in weight, and it has been used in development work on improving the creep strength of titanium alloys up to 350/400 deg. Cent., using a criterion of 0·1 per cent total strain in 100/300 hours. In the new plant, which is due to be completed by the end of this year, ingots of up to 300 lb will be produced in sizes up to 12in diameter, and from 300 lb to 2000 lb up to 20in diameter. The initial output of the plant will be about 350 tons of ingots a year, and provision is being made in its layout for an expansion of capacity when required. We are informed that the firm will manufacture various grades of titanium within the two main alloy categories—Alpha and Alpha plus Beta—under the trade name " Hylite." The alloys will be available in the following forms : hand forgings, drop stampings, rolled or hammered bar, ingots or billets for forging.

# British Patent Specifications

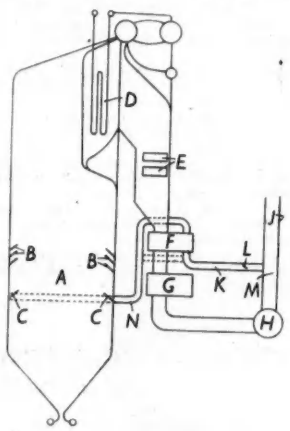
*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.*

*Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.*

## STEAM GENERATORS

**735,034.** Aug. 31, 1951.—STEAM GENERATING AND SUPERHEATING INSTALLATIONS, The Superheater Company, Limited, and Leonard Clement Southcott, both of 53, Haymarket, London, S.W.1.

It is an object of the invention to provide an improved steam generating and superheating installation incorporating recirculation of gases in which the high final superheated steam temperature will be obtained without there resulting an increase in the temperature of the gases leaving the installation, or an unduly high temperature in the furnace chamber, and in which the gases of combustion which have flowed through the installation and are returned to the furnace for recirculation with fresh gases will be distributed uniformly and without detriment to the efficiency of the combustion. The drawing shows the furnace *A* fired by burners *B* at its corners. The

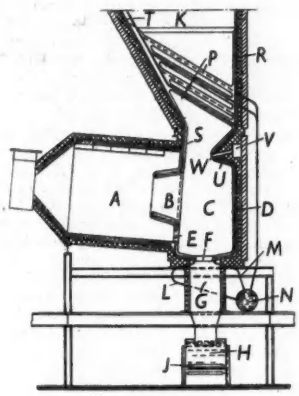



No. 735,034

nozzles *C* discharging gases into the furnace, for recirculation through the installation are below the fuel burners. Means may be provided for varying simultaneously the inclination to the horizontal of the fuel burners and return gas nozzles *C* in order to regulate the temperature of the gases leaving the furnace and flowing over the superheater *D*. The gases, after flowing over the superheater, flow over the economiser *E* and through a heat exchanger *F* before flowing to the normal air preheater *G*. After flowing through the preheater they are delivered by an induced draught fan *H* towards the chimney or stack *J*. The heat exchanger *F* provided according to the invention is located at a suitable point in relation to the fan *H* and connected by a duct *K* to the main duct between the fan and the stack *J*. Dampers *L*, *M* in both ducts regulate the gas flow through the heat exchanger *F*. Thus a proportion of the gases delivered by the fan *H*, determined by the setting of these dampers, flows through the heat exchanger *F* and is heated prior to delivery to the furnace nozzles *C* through a duct *N*. At the same time the temperature of the gases entering the air preheater *G* is lowered. The provision of the gas reheating heat exchanger *F* thus has the effect of maintaining the temperature of gases leaving the unit at the desired figure whereas the normal effect of gas recirculation is to raise the exit gas temperature. By tilting the gas nozzles *C* in unison with the fuel burners *B* the gases are introduced in streams parallel with the air and fuel streams delivered by the burners, and a greater uniformity of gas distribution is obtained without detriment to the efficiency of combustion. While the invention has been described as applied to a plant with a furnace fired by tilting burners at the corners the invention is not restricted to units, having burners so located.—*August* 10, 1955.

**734,997.** August 14, 1953.—SLAG-TAP FURNACES, Babcock and Wilcox, Ltd., Babcock House, Farringdon Street, London, E.C.4.

The invention relates to slag-tap furnaces of the kind in which a primary furnace chamber is arranged to discharge towards the rear wall of a secondary furnace chamber between the primary furnace chamber and a fluid-cooled radiation chamber at the inlet of which is a slag screen of fluid-cooled tubes, and more particularly to such furnaces in which the primary furnace chamber is a cyclone furnace chamber. In the drawing a cyclone furnace chamber *A* is arranged to discharge gases through an inwardly tapering gas outlet throat *B* into a secondary furnace chamber *C* towards the rear wall *D*. The cyclone furnace chamber is formed with a slag outlet *E* for the discharge of molten slag into the secondary chamber. If desired, several cyclone furnace chambers may be arranged side by side to discharge into the secondary chamber. The bottom of the secondary furnace chamber *C* has an outlet *F* for the discharge of molten slag through a shaft *G* into the water trough *H* of a scraper conveyor *J*. Above the secondary furnace chamber *C* is a radiation chamber *K*, and the walls of the two chambers are lined with vapour generating tubes, the tubes in the secondary furnace chamber and at the bottom of the radiation chamber being covered with refractory material. In the drawing three groups of tubes *L*, *M*

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and *N* are shown extending from a lower drum *O* towards an upper drum, not shown. The tubes of the group *L* help to line the bottom of the secondary furnace chamber, to form the throat *B* and the front wall of the secondary furnace chamber and to line the front wall of the radiation chamber. The tubes of the group *M* help to line the bottom of the secondary furnace chamber and line the rear wall of that chamber. Some of these tubes line the rear wall of the radiation chamber, whilst others form the lower inclined rows of a tubular slag screen *P* at the inlet to the chamber and help to line the front wall of the radiation chamber. The tubes of the group *N* form two upper inclined rows of the slag screen *P* and help to line the front wall of the radiation chamber. The rear wall *D* of the secondary furnace chamber and the rear wall *R* of the radiation chamber are vertical, whilst the upper part of the front wall *S* of the secondary furnace chamber and the front wall *T* of the radiation chamber in the neighbourhood of the slag screen *P* slope forward above the cyclone furnace chamber to give an increasing flow area for the gas stream passing up in the radiation chamber. Below the tubular slag screen the rear wall *D* of the secondary furnace chamber is formed with an inward, wedge-shaped projection *U* having a rounded tip and covered by tubes of the group *M*. Extending through the projection *U* from a distributing duct *V* in a direction normal or approximately normal to the direction of flow of the furnace gas stream past the tip of the projection are a number of nozzles *W* through which air or cooled furnace gases can be blown into the gas stream. In operation, the gases from the cyclone furnace chamber *A* are discharged at substantial velocity through the throat *B* and across the secondary furnace chamber *C* towards the rear wall *D*. Gases passing up and encountering the projection *U* are directed forward, with the result that the stream of furnace gases is caused to fill the whole cross-section of the chamber *K*. By directing air or gas through the nozzles *W* the furnace gases may be urged forward to a greater extent and turbulence may be increased. When, as in the furnace illustrated, the rear walls of the secondary furnace and radiation chambers are in alignment, whilst the front wall of the radiation chamber is inclined forward to effect a progressive widening of the radiation chamber, the wedge-shaped projection may with advantage be disposed at the rear wall of the radiation chamber behind the slag screen.—*August* 10, 1955.

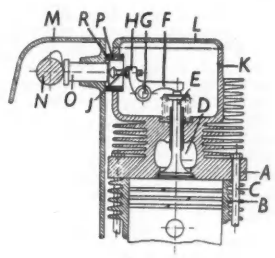
## INTERNAL COMBUSTION ENGINES

**734,980.** June 1, 1953.—TWO-STROKE CYCLE ENGINES, Aktieselskabet Burmeister and Wain's Maskin- og Skibsbyggeri, No. 4, Strandgade, Copenhagen, K-, Denmark.

The specification describes a two-stroke internal combustion engine, preferably a diesel engine, with one or more exhaust gas-turbine-driven blowers. The exhaust from an engine cylinder to the exhaust turbine or turbines takes place in a single stage and as a whole is effected through a mechanically acutated valve or valves of a set of piston-controlled ports. The invention is characterised in that the supply of the full quantity of scavenge air necessary for the engine is provided solely by the exhaust gas-turbine-driven blower or blowers. The exhaust ports or valves are arranged to open early so that a comparatively great part of the energy of the exhaust gas remains at the disposal of the exhaust turbine or turbines. The scavenge ports as well as the exhaust ports or valves of the engine have relatively large passage areas, so that the flow velocity through them and thereby the pressure drop of the scavenge air in the cylinder is slight, and a relatively large pressure drop is at the disposal of the exhaust turbine or turbines and that the above conditions are so arranged that not only at normal load, but at any optional load between idling and highest output the full quantity of scavenge air corresponding to the particular momentary load is supplied. The conditions are so chosen that at the most unfavourable loads between idling and highest output there is a balance or an approximate balance between the output of the turbine and the blower work necessary for the scavenging at the particular loads.—*August* 10, 1955.

**734,268.** November 7, 1951.—VALVE GEAR FOR ENGINES WITH CYLINDER HEAD VALVES, Lanova A.-G., 16, Bahnhofstrasse, Zurich, Switzerland.

As shown in the drawing, the cylinder head *A* and the cylinder *B* are connected to the lower part of the crankcase by means of bolts *C*, which are designed as expansion screws. The engine valves *D*, only one of which is shown, are arranged in the wall of the cylinder head which faces the bore so that their stems *E* are parallel with the central line of the cylinder. Each valve is actuated by a rocker in the form of a bell-crank lever *F* rocking about a shaft *G*. One arm of the rocker *F* is substantially at right angles with respect to the axis of the valve stem and it engages directly the head of the valve stem. The other arm *H* extends in a direction substantially parallel with the central line of the cylinder, and this arm is provided with a screw *J*, which adjusts the clearance of the valve gear. The members of the valve gear are accommodated within a box or casing *K* which forms part of the cylinder head and is closed by a lid *L*. Adjacent to the box, an extended part *M* of the crankcase is shown. Within this

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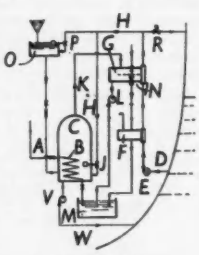
extended part is a camshaft *N*. Each cam co-acts with a cam follower in the form of a tappet *O*, which is so disposed that its longitudinal axis is at right angles to the centre line of the cylinder. Each tappet extends through and is guided by a corresponding opening in the crankcase wall adjacent the valve gear box, and the projecting end of the tappet forms a thrust face. The screw bolt *J* extends through an opening in the valve gear box *K* in the range of the cam-actuated tappet *O*, and the head of the screw bolt is in contact with the thrust face of the tappet. Thus, the movement of the tappet is transmitted to the bolt *J* in a direction perpendicular to the centre line of the cylinder, and it will be understood that the bolt is free to move with respect to the thrust face, from an initial central position, upwards or downwards, so that it is allowed to attain a position which is determined by an elongation of the cylinder different from that of the crankcase, without affecting the transmission of the actuating movement from the camshaft to the engine valve. Thus, the valve gear, once adjusted, will operate in the same manner at all operational conditions. In order to prevent oil leakage at the point where the bolt *J* extends through the gap between the valve gear casing *K* and the extended part of the crankcase *M*, a threaded cylindrical sleeve *P* is provided which screws into the wall of the casing. A sealing ring *R* of an oil-proof resilient material is disposed between the crankcase and the free end of the sleeve *P* so that it can be pressed against the wall of the crankcase by rotating of the sleeve. The valve gear for the other valve or valves is designed in the same manner and the specification includes also a design for a horizontal engine.—*July* 27, 1955.

### DISTILLERS AND EVAPORATORS

**734,755.** May 7, 1951.—TREATMENT OF SEA-WATER FOR EVAPORATING PLANTS, G. & J. Weir, Limited, Harold Hillier and Frank Bruce Ling, all of the company's address, Holm Foundry, Cathcart, Glasgow.

The invention relates to evaporating and distilling plants in which sea-water is evaporated for the purpose of removing undesirable solids, the vapour so produced being subsequently condensed, the condensate being suitable for consumption as drinking water or for use in high-pressure steam boilers. The invention utilises a chemical compound which can be safely and easily transported and which, on injection into an evaporator which is used for evaporating sea-water, will prevent the formation of scale or sludge on the heating surface of the evaporator. Referring to the drawing steam is supplied through a pipe *A* to a heating surface *B* within an evaporator shell *C*. Feed water is drawn from the sea through a pipe *D* by a pump *E* which discharges through an air ejector condenser *F* and an evaporator vapour condenser *G* by way of a pipe $H_1$ and feed regulator *J* to the evaporator shell *C*. The vapour resulting from the heat transfer across the heating surface *B* is led by way of a pipe *K* to the condenser *G*, where it is condensed, the resulting condensate being removed by a pump *L* which discharges into a distilled water tank *M*. The evaporator shell *C* is operated under vacuum which is maintained by an ejector *N*, the discharge from the ejector being condensed in the ejector condenser *F*; the resultant drainage drains by way of a pipe to the tank *M*. A portion of the sea-water discharged by the pump *E* through the air ejector condenser *F* and the evaporator vapour condenser *G* is discharged overboard by way of a spring-loaded valve *R*. Some of the water discharged by the pump *E* is led through a float-controlled valve *P* to a small tank *O*. The selected salt is added by way of a funnel into the water in the tank *O*. The water to which the salt has been added is led by gravity into the evaporator shell *C* under the control of a regulating valve. The pipeline is preferably provided with sight glass to permit the rate of flow to be observed. It will be understood that the proper weight of the added salt, which is preferably ferric chloride, is intimately mixed in the water in the tank *O* before it is injected into the evaporator shell, the amount of water and ferric chloride so fed being proportional to the supply of sea-water to the evaporator shell. Brine is withdrawn continuously from the evaporator shell by a pump *V* which discharges the brine overboard through a pipe *W*. Two other modified arrangements of evaporators are also shown in the specification.—*August* 10, 1955.

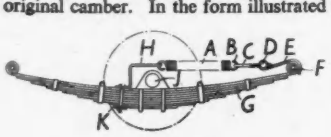


No. 734,755

### ROAD TRANSPORT

**734,886.** April 23, 1953.—THE SPRINGING OF VEHICLES, Toledo Woodhead Springs, Ltd., Clifton Works, Neepsend Lane, Sheffield, 3. (*Inventor: Frank Woodhead.*)

The invention concerns semi-elliptic plate or leaf springs such as employed in the mounting of the chassis frame and axles of motor vehicles and is applicable to road vehicles or vehicles which run on tracks or rails. The object of the invention is an auxiliary springing system which will come into action on change of length of the main spring to take part of the load and assist the springing to return to its normal position, and which can also serve to restore worn or weak springs to their original camber. In the form illustrated in the drawing the device comprises a coil spring *A*, the end *B* of which is attached to a U-bolt *C*, both legs of which are threaded and pass through a transverse bar *D* on which is pivotally mounted a member *E* hooked at its free end to fit over the outer end *F* of the top leaf of the main spring *G*. The other end of the coil spring *A* is hooked to a bracket *H* which is clamped on the spring *G* at a point further away from the end *F* than the axle *J* by the clamping plate *K*. The effective overall length of the device can be adjusted by the nuts on the ends of the legs of the U-bolts *C*. When a load is applied to the spring *G* and it is deflected it will lengthen and the consequent extension of the coil spring *A* will assist in overcoming the load and also in restoring the spring to its original position when the load is removed. Several modified arrangements for light and heavy vehicles are also shown in the specification.—*August* 10, 1955.



No. 734,886

## Launches and Trial Trips

CHENONCEAUX, oil tanker; built by the Chantiers de France for the Société Maritime des Petroles B.P.; length overall 669ft 4in, length between perpendiculars 630ft 9in, breadth moulded 86ft, depth 46ft 8in, draught loaded 35ft 1in, deadweight 32,650 tons, load displacement 42,440 tons; thirty oil cargo tanks, one cargo pump room, two 1000-tons per hour cargo oil pumps, two 500kW turbine driven alternators, one 75kW diesel driven alternator; one set of double reduction geared Parsons turbines built by the Compagnie Electro-Mecanique, maximum power 15,200 s.h.p. at 108 propeller r.p.m., service power 14,000 s.h.p., service speed 16·4 knots, steam supplied at 600 lb per square inch and 850 deg. Fah. by two Penhoet P.41 watertube boilers.—Trial August.

TYNEMOUTH, cargo ship; built by Smith's Dock Company Ltd., for the Burnett Steamship Company Ltd.; length between perpendiculars 350ft, breadth moulded 51ft, depth moulded to main deck 25ft 3in, deadweight 5505 tons on 21ft ¼in draught, trial speed 12¼ knots, timber freeboard gives 22ft 2in summer draught and 5998 tons deadweight; four holds, two 10-ton and six 5-ton derricks, steam deck machinery; triple expansion steam engine cylinder diameters 18¾in, 30¼in, 52in by 36in stroke, Bauer-Wach exhaust turbine, 1550 i.h.p. at 90 r.p.m., steam supplied at 220 lb per square inch and 580 deg. Fah. by two multitubular boilers.—Trial August.

DOLIUS, cargo and passenger liner; built by Harland and Wolff, Ltd., for Alfred Holt and Co.; length overall 485ft, length between perpendiculars 452ft 9in, breadth moulded 62ft, depth moulded 35ft 3in, gross tonnage 7800; twelve passengers; two complete steel decks, four main cargo holds, derrick complement includes one to lift 70 tons, electric derrick machinery, two 450kW diesel driven generators, one 350kW gas turbine driven generator; Harland and Wolff, single-acting, two-cycle, opposed piston super-charged oil engine, six cylinders 750mm diameter by 2000mm combined stroke.—Launch August 4th.

FOYLEBANK, cargo liner; built by Harland and Wolff, Ltd., for the Andrew Weir Shipping and Trading Co., Ltd.; length overall 455ft, length between perpendiculars 425ft, breadth moulded 59ft, depth moulded to shelter deck 38ft 3in, gross tonnage 5671; two complete steel decks, four main cargo holds, one 25-ton, fourteen 5-ton and two 3-ton derricks, electric deck machinery, three 175kW diesel driven generators; Harland and Wolff two-stroke, single-acting, opposed piston diesel engine, six cylinders 620mm diameter by 1870mm combined stroke, 118 r.p.m.—Trial August 4th.

SAMUEL ARMSTRONG, grab hopper dredger; built by Henry Robb, Ltd., for the Ipswich Dock Commission; length overall 135ft, breadth moulded 28ft 6in, depth moulded to upper deck 12ft, mean-draught 10ft 6in, hopper capacity 300 cubic yards, designed speed 10 knots; diesel driven grabbing crane, working radius 30ft, working depth 50ft, one 70 cubic foot mud grab, one 55 cubic foot sand grab; two 25kW diesel driven generator sets; Crossley two-stroke diesel engine 700 b.h.p. at 350 r.p.m.—Launch August 18th.

WARRINGA, cargo liner; built by The Burntisland Shipbuilding Company, Ltd., for Huddart Parker, Ltd., Melbourne, Australia; length between perpendiculars 320ft, breadth 49ft 6in, depth moulded to shelter deck 29ft 8in, 4280 tons deadweight; four cargo holds, one 25-ton, four 10-ton and twelve 5-ton derricks, electrical deck machinery, four 140kW diesel driven generators; Ailsa-Doxford opposed piston oil engine, four cylinders 480mm diameter by 1660mm combined stroke, 2000 b.h.p.—Trial July.

BURWAH, raised quarter deck cargo ship; built by The Burntisland Shipbuilding Company Ltd., for Australian Steamships Proprietary, Ltd.; length between perpendiculars 290ft, breadth 44ft 6in, depth moulded 20ft 10in; four cargo holds, ten 5-ton and two 7-ton derricks, electric deck machinery, four 100kW diesel driven generators; British Polar diesel engine, nine cylinders 340mm diameter by 570mm stroke, 1440 b.h.p.—Launch August 18th.

CASTILIAN, cargo ship; built by Alexander Stephen and Sons, Ltd., for the Westcott and Laurance Line, Ltd.; length between perpendiculars 350ft 6in, breadth moulded 53ft, depth to shelter deck 32ft 9in, gross tonnage 3802, 5440 tons deadweight; four holds, one 35-ton, two 10-ton, eight 7-ton and two 5-ton derricks, steam deck machinery; two steam driven generators; C.M.E. direct acting inverted triple expansion engine and Bauer-Wach exhaust turbine, steam supplied at 225 lb per square inch by three cylindrical Scotch boilers.—Trial August.

TROUTPOOL, cargo liner; built by Joseph L. Thompson and Sons, Ltd., for Sir R. Ropner and Co. (Management), Ltd.; length between perpendiculars 440ft, breadth moulded 61ft 4in, depth moulded 39ft 9in, mean draught 27ft 9in, deadweight 10,200 tons; six holds, eighteen derricks, electric deck machinery; service speed 15½ knots; N.E.M.-Doxford oil engine, six cylinders 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m.—Trial August.

## Catalogues and Brochures

ELECTRO-HYDRAULICS, Ltd., Liverpool Road, Warrington.—Industrial valves brochure.

PRECISION HEATING, LTD.—Leaflet describing the P.H. infinitely variable speed electric motor controller.

ALUMINIUM UNION, Ltd., The Adelphi, London, W.C.2.—Brochure describing aluminium foil for roofing.

PADDON PRECISION TOOLS, Ltd., 26, Glenburnie Road, London, S.W.17.—Leaflet describing the "Sizer" boring head.

BRITISH JEFFREY-DIAMOND, Ltd., Stennard Works, Wakefield, Yorks. Publication 1508, describing mud hog crushers.

LACRINOID PRODUCTS, Ltd., Gidea Park, Essex.—Brochure describing a new range of barrel finishing compounds.

THE POWER GAS CORPORATION, Ltd., Stockton-on-Tees.—Brochure describing the "Segas" catalytic oil-gas process.

JAMES GORDON AND CO., LTD., Dalston Gardens, Stanmore, Middlesex.—Leaflet No. H.54 on three-element feedwater control.

BRAITHWAITE AND CO., STRUCTURAL, Ltd., "The Moorings," Church Road, Great Bookham, Surrey.—Brochure on pressed steel tanks.

DUNLOP RUBBER CO., LTD., (G.R.G. Division), Cambridge Street, Manchester, 1.—Leaflet on silicone rubber glass cloth insulation tape.

LANCASHIRE DYNAMO AND CRYPTO, Ltd., Trafford Park, Manchester, 17.—Pamphlet illustrating and describing L.D.C. motors for power stations.

THE QUASI-ARC CO., LTD., Bilston, Staffordshire.—Leaflet giving information on "Ferron" electrodes specially recommended for welding heavy sections in mild steel.

BLAW-KNOX, Ltd., 94, Brompton Road, London, S.W.3.—Publication "BK-216," superseding "BK-128," describing and illustrating Blaw-Knox steel road forms.

## Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### BRITISH INSTITUTION OF RADIO ENGINEERS

*Wed., Sept. 28th.*—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Extending the Limits of Resistance Measurement Using Electronic Techniques," G. I. Hitchcox, 6.30 p.m.

### ELECTRIC RAILWAY SOCIETY

*Sat., Sept. 3rd.*—Visit to Stonebridge Park Power Station and Overhaul Works, 1.40 p.m. (Stonebridge Park Station).

### ENGINEERING, MARINE AND WELDING EXHIBITION AND THE FOUNDRY TRADES EXHIBITION

*Thurs., Sept. 1st, to Thurs., Sept. 15th.*—Olympia, London. Open each week-day from 10 a.m. to 8 p.m.

### INCORPORATED PLANT ENGINEERS

*Tues., Sept. 6th.*—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2. Further discussion on the 1955 conference paper, "Is There a Future for Tracked Earth-Moving Plant in View of the Development in Rubber-Tyred Earth-Moving Plant?" 7 p.m.—EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, Members' Evening, 7 p.m.

*Wed., Sept. 7th.*—LEICESTER BRANCH: College of Art and Technology, The Newarkes, Leicester, "Underwater Television," 6.30 p.m.

*Thurs., Sept. 8th.*—GLASGOW BRANCH: Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow, "Developments in Machine Tools," J. R. Young, 7 p.m.

*Mon., Sept. 12th.*—DUNDEE BRANCH: Mathers Hotel, Dundee, "The Use of Breathing and Resuscitating Apparatus," 7.30 p.m.

### INSTITUTE OF PETROLEUM

*Wed., Sept. 14th.*—26, Portland Place, London, W.1, "Modern Crude Oil Loading Techniques at Mina-al-Ahmadi, Kuwait," J. M. Dougary, 5.30 p.m.

### INSTITUTE OF ROAD TRANSPORT ENGINEERS

*Tues., Sept. 6th.*—NORTH REGIONAL CENTRE: Victoria and Station Hotel, Preston. Talk on Firestone Tyres followed by three films. 7.30 p.m.

*Fri., Sept. 9th.*—SOUTH WALES GROUP: South Wales Institute of Engineers, Park Place, Cardiff, "An Approach to the Organisation and Operation of a Large Composite Fleet," R. H. Patman, 7 p.m.

### INSTITUTE OF WELDING

*Wed., Nov. 2nd, to Fri., Nov. 4th.*—Autumn Meeting, London.

### INSTITUTION OF ENGINEERING DESIGNERS

*Mon., Sept. 5th.*—NORTH EAST BRANCH: 6, Higham Place, Newcastle upon Tyne, Two short lectures, "The Metric System," by T. J. Skiedrzynski, and "The Assistant Works Engineer," by E. Watson, 7.15 p.m.

*Tues., Sept. 6th.*—The Bull Hotel, Rochester, Kent, "Automation in Industry and Examples in Electronics," R. D. Carter-Pedler and J. A. Sargrove, 7 p.m.